13.1 CYBER SECURITY AND ITS RELATED ISSUES

13.1.1 Cybercrime

Any crime that involves a computer and a network is termed as Cybercrime. Here, the computers may or may not have played an instrumental part in the commission of a crime.

Cybercrime spans activities like hacking, spam, online fraud, obscene or offensive content, harassment, cyberterrorism and cyber warfare. It usually includes high-profile crimes, particularly those surrounding hacking, copyright infringement, child pornography and child grooming. The major issue of privacy arises when confidential information is lost or intercepted, in a lawful manner or otherwise.

13.1.2 Measures to Control Cybercrime in India

The Information Technology (Amendment) Act, 2008, serves as the legal framework for tackling cybercrime in India. The original Act of 2000 contained provisions on cybercrimes related to online transactions. The legal framework was required to be strengthened and amended due to several new forms of computer crime, misuse and fraud taking place. To tackle new forms of cybercrimes like sexually explicit material in electronic form, video terrorism and breach of confidentiality and leakage of data by intermediary and e-commerce frauds, the amended Act of 2008 came into force. As part of cyber security efforts of the government, a holistic effort approach is being followed, involving research and development in cyber security. Several research and development projects have been initiated for basic research and indigenous development of technology in this area.

13.1.3 Cyber Security

13.1.3.1 Basics of Cyber Security

The processes and mechanisms ensuring protection of computer-based information against unauthorised access, transfer, modification or destruction (whether accidental or intentional) is termed as Cyber Security. It deals with security threats such as hacking, malware, cybercrime, cyberterrorism, data theft, etc. It studies these threats and the features of computer systems and networks that make them vulnerable to these threats and then try to come up with measures to prevent these threats and find solutions after the computer is already affected. Cyber security companies **produce anti-virus programmes** to prevent infection from viruses and heal infected computers. Cyber security is also concerned with **developing threat-resistant firewalls, encryption** and **passwords** for protection against hacking and data theft.

13.1.3.2 Significance of Cyber Security

With the expansion of Internet and computer systems, the responsibility of these is getting more and more complex and interdependent. Thus, cyber security has become a serious concern as new security threats emerge every day. Poor cyber security may make government, business and personal computers vulnerable to these threats. New viruses are known to cripple businesses worldwide, causing billions of dollars of damages every year. Cyber security is not just an issue that concerns individuals and businesses but also government, since as it has national security dimensions. For example, if military computers are not adequately protected against hacking, enemy countries may steal sensitive data.

13.1.3.3 Cyber Security in India

In India, because of the thriving IT industry, large-scale use of computers by governments, especially e-governance and the growing usage of personal computers, cyber security has emerged as an important issue that requires a national-level response. The legal framework for cyber security in India is the Information Technology (Amendment) Act, 2008. **The Union Government had set up an Inter Departmental Information Security Task Force (ISTF) with National Security Council as the nodal agency to highlight the growing threat to information security in India and focus related actions.**

The issues were studied and deliberated by Task Forces relating to cyber security and recommendations were made. Considering the recommendations of the **ISTF, the following initiatives** have been taken by the Government:

1. **Indian Computer Emergency Response Team (CERT-In)** has been established to respond to

the cyber security incidents and take steps for prevention of recurrence of the same.

2. Public Key Infrastructure or PKI (i.e., user and verifier).
3. To support implementation of Information Technology Act and **promote use of Digital Signatures,** adequate infrastructure has been set up.
4. Research and Development activities have been supported by GOI through premier academic and Public Sector Institutions in the country.
5. **Government cyberspace and critical infrastructure have been developed.**
6. Information Security Education and Awareness Programme has been launched all over India.

The Government is also following a holistic strategic approach for the long term. The approach includes research and development, legal framework, security incidents, early warning and response, best security policy compliance and assurance, international cooperation and security training.

8. The **Crisis Management Plan was formulated** in April 2010 to deal and counter cyber-attacks and cyberterrorism. It is to be implemented by all ministries and departments of central and state governments.

13.1.4 Cyber Check

It is an **advanced cyber forensics tool kit** for analysing and viewing evidence files, indigenously **developed by the Centre for Development of Advanced Computing (CDAC),** for use by law enforcement agencies. A branch of forensic science pertaining to obtain legal evidence found in computers and digital storage media is termed as computer forensics.

13.1.5 Cyberterrorism

13.1.5.1 Basics of Cyberterrorism

Cyberterrorism describes the acts of deliberate, large-scale disruption of computer networks, especially personal computers connected to the Internet. It is performed by the means of tools such as computer viruses.

Cyberterrorism is a controversial term. Some authors choose a very narrow definition, relating to deployments, by known terrorist organisations. By this narrow definition, it is difficult to identify any instances of cyberterrorism. Hence, a more general definition includes, for example, as 'The premeditated use of disruptive activities, or threats against computers and/or networks, with the intention to cause harm or further social, ideological, religious, political or similar objectives or to intimidate any person in furtherance of such objectives'.

13.1.5.2 Different Forms of Cyberterrorism

Cyberterrorism can take various forms:

1. **Terrorist propaganda on the Internet:** The ultimate aim of a physical terrorist attack is to terrorise a target population. It involves spreading a feeling of fear and therefore, adequate coverage in the media is very important for terrorists to succeed. The Internet is one of the media that is used by terrorists to spread terror, promote terrorist ideologies, organise terrorist activities by connecting terrorists in different parts of the world, etc.
2. **Privacy violation:** A lot of private information is present on the Internet and computers. This includes passwords, encryption keys, images and videos, sensitive files, etc. Cyber terrorists may steal these resources or threaten it. Right to privacy is part of the Right to Life of Article 21 of the Constitution. Various provisions of the Information Technology Act, 2000, protect the online privacy rights of the citizens.
3. **Attacks on government properties:** Governments maintain large databases and a large number of government computers are connected to the Internet. This makes them susceptible to hostile attacks mainly in the form of theft of sensitive government information, valuable government secrets including those relating to defence and national security, passwords and other private information of government officials, etc. E-governance systems may be hacked and disrupted, causing great inconvenience to public and even threatening day-to-day government activities. A similar attack may be made by cyber

terrorists on computers and networks of private companies and individuals.

13.1.5.3 Distributed Denial of Service Attack

The cyber terrorists may also use the method of Distributed Denial of Service (DDoS) to overburden the computer systems and networks of governments, armed forces and businesses. This involves sending a large number of web requests to servers, overloading them and ultimately leading to their collapse. This results in serious disruption. It results in immense pecuniary and strategic loss to government and its agencies.

13.1.6 Combating Cyberterrorism

In India, **the Information Technology Act, 2000, has laws regarding privacy violations, information theft, DDoS attacks, network damage and disruptions.** The Council of Europe Convention on Cybercrime, established in 2004, is the first International treaty for fighting against computer crime.

13.1.7 Cyberwarfare

13.1.7.1 Basics of Cyberterrorism

Politically motivated hackers aiming to conduct **sabotage and espionage** lead to Cyber warfare. It being an information warfare is sometimes seen analogous to conventional warfare, although this analogy is controversial in terms of its accuracy and its political motivation.

Thus, cyber warfare is described as 'actions by a nation-state to penetrate another nation's computers or networks for the purposes of causing damage or disruption'. Cyber warfare can be described as **'the fifth domain of warfare'**, which has become just as critical to military operations as land, sea, air and space. In spite of its growing threat, it has been the least common warfare and so far has not been used effectively.

President Barack Obama, in 2009, declared America's digital infrastructure to be a 'strategic national asset', and thereafter, the Pentagon set up its new US Cyber Command (USCYBERCOM) in May 2010, to defend American military networks and attack other countries' systems. A cyber-security and 'operations centre' is also established then by United Kingdom.

13.1.7.2 Cyberwarfare Consists of Many Different Threats

1. **Cyber Espionage:** The includes any practice meant to obtain secret information from individuals, competitors, rivals, groups, governments and enemies to take military, political or economic advantage.
2. **Cyber Vandalism:** This usually involves **hacking enemy websites** and defacing the web pages or plant propaganda messages.
3. **DDoS Attack:** Attempt to make a computer resource unusable by persons or groups who disrupt an Internet site or service. In cyber warfare, DDoS (distributed denial-of-service) attacks mainly involve targeting of government and military websites.
4. **Sabotage:** Military activities using computers and satellites for coordination are often at risk of equipment disruption. Power, water, fuel, communications and transportation infrastructure, all of them may be vulnerable to disruption, as they are increasingly controlled by computer systems. Particularly, power transmission systems and telephonic systems including cell phones are susceptible to cyber warfare. Even interception or replacement can affect orders and communications. Massive power or communication outages caused by a cyber-attack could disrupt the economy, distract from a simultaneous military attack or create a national crisis.

13.1.7.3 Cyberwarfare and India

13.1.7.3.1 India's Vulnerability

In recent times, cyber-attacks resemble political conflict, leading to warning from experts of the unfolding of a 'Cyber Cold War'. It is said that massive cyber-attacks may precede future wars. India appears to be extremely vulnerable due to huge growth in government state-wide area networks and 25 mission e-governance mode projects, in addition to electrical grid, cell phones, oil and gas infrastructure. This is on top of the private industry, especially the banking and finance sector deploying huge number of online transactions.

13.1.7.3.2 Response

The main agency dedicated to defend India's IT infrastructure is **Computer Emergency Response Team (CERT)** within the Department of Information Technology. It performs its functions in coordination with the National Informatics Centre, the government's service provider. Dedicated cyber warfare groups operate in the **Defence Intelligence Agency (DIA)** and India's technical intelligence organisation **National Technical Research Organisation (NTRO).**

The Indian Army recently announced that an impenetrable and secure wide area network exclusively for army's function and use has been established functioning. The army has its own cyber security policy, a Computer Emergency Response Team (CERT) and its own cyber audit process, which is conducted by cyber security personnel.

3.3 Shortcomings Exist in India's Cyber Warfare Capabilities

Dedicated cyber warfare groups operate in the DIA and NTRO but these are tasked only with **offensive cyber warfare and not with defending** against cyber-attacks.

2. **India spends less than $1 million on offensive cyber warfare.** There are a handful of experts available. On the other hand, China has an annual budget of $55 million and employs thousands of hackers. The US and some European nations are even ahead.
3. **India cannot counterattack,** but various nations can. For example, **a secure operating system 'Kylin' has been developed by the Chinese** as an effective protection from such attacks. Not only this, **a secure microprocessor has also been developed by them.** This microprocessor, unlike the US-made chips, which most computers in India use, is known to be hardened against external access.
4. India, in spite of being an IT-superpower, is almost **entirely dependent on external sources,** be it hardware or software. **Even for all anti-virus programmes, network protocols and network hardware components,** India depends on external sources. Such vulnerable operating systems could lead to massive DDoS attacks.

13.1.7.3.4 A Long-Term Response Involves in Cyber Security

1. **A dedicated cyber security organisation,** which employs police and armed forces personnel that can initiate developing a strategy to protect national information infrastructure.
2. **Increasing the cyber warfare budgets** and inducting more personnel.
3. **Setting up a national centre for coordinated response to cyber-crime** between various law-enforcement agencies, Internet Service Providers (ISPs) and high-quality researchers within the country.
4. **Carrying out extensive information security audits of government networks and encouraging the private sector to do the same.** The idea would be to identify security gaps to determine exactly what the problem is and try to address its security requirement.
5. A software and hardware policy intended for development of **secure indigenous microprocessors and operating systems,** so that more and more computers use these and make computers in India, in general, more resistant to cyber-attacks.
6. There is a view among officials and experts that the **Indian government needs to evolve a national security policy,** which should be implemented in all the government departments.

In May 2010, the Indian government announced several measures designed to address the cyber security challenge:

- A task force was formed by the government to devise a plan for building open source, indigenous operating systems, intended at reducing dependence on foreign hardware and software vendors.
- The government established a Crisis Management Plan against cyber-attacks, which all central ministries, state governments and critical sectors need to implement.

In August 2010, at a high-level security meet chaired by the **National Security Advisor (NSA), the government made several more proposals:**

1. **Set up a cyber-warfare infrastructure,** manned by a small army of software professionals, for spying

purposes on the classified data of hostile nations by hacking into their computer systems.

2. According to the proposal, the responsibility for creating cyber-offensive capabilities is on the National Technical Research Organisation (NTRO) and Defence Intelligence Agency (DIA).
3. Further plans of the government include amplification of the efforts to strengthen its cyber armour. It is proposed that to check all types of hardware and software being sourced by departments for spyware, **a National Testing Centre will be established.** It will prevent India's computers from coming under attack.
4. The NSA has also asked the DRDO and DIA to **magnify efforts against electromagnetic-pulse bombs that can interrupt wireless signals inside the country.** As per NSA's directives, the DIA has to harden its **Transient Electro Magnetic Pulse Emanations Standards,** known as TEMPEST in military parlance. Hardening TEMPEST includes lower chances of interception of data transferred by defence agencies through Internet.
5. The introduction of cyber security in the curriculum of NTs and educational institutes is as per the directives of the National Security Council Secretariat to the HRD and IT ministries.

13.1.8 National Cyber Security Policy, 2013

Indian Government announced National Cyber Security Policy, 2013 with these important features:

- To form a secure and flexible cyber space.
- To have a safe and secure cyber ecosystem and generate belief and trust in IT transactions.
- To setup a 24 × 7 National Critical Information Infrastructure Protection Centre (NCIIPC).
- To test all Information and Communication Technology (ICT)-based products and certifying them.
- To create workforce of 500,000 professionals in the field of ICT.

13.1.9 Cyber Crime Coordination Centre

The ***Indian Cyber Crime Coordination Centre (I4C)*** was inaugurated by the government in January 2020. The scheme to set up I4C was ***approved in October 2018,*** to deal with all types of cybercrimes in a comprehensive and coordinated manner.

About the Indian Cyber Crime Coordination Centre

It was set up under the newly created ***Cyber and Information Security (CIS) division*** of the MHA (Ministry of Home Affair).

It has seven components:

1. National Cyber Crime Threat Analytics Unit,
2. National Cyber Crime Reporting Portal,
3. National Cyber Crime Training Centre,
4. Cyber Crime Ecosystem Management Unit,
5. National Cyber Crime Research and Innovation Centre,
6. National Cyber Crime Forensic Laboratory Ecosystem, and
7. Platform for Joint Cyber Crime Investigation Team.

Functions

- The I4C will assist in centralising cyber security investigations, prioritise the development of response tools and bring together private companies to contain the menace.

Objectives

- To act as a nodal point in the fight against cybercrime.
- Identify the research problems/needs of LEAs and take up R&D activities in developing new technologies and forensic tools in collaboration with academia/research institutes within India and abroad.
- To prevent misuse of cyber space for furthering the cause of extremist and terrorist groups.
- Suggest amendments, if required, in cyber laws to keep pace with fast changing technologies and International cooperation.
- To coordinate all activities related to implementation of Mutual Legal Assistance Treaties (MLAT) with other countries related to cybercrimes in consultation with the concerned nodal authority in MHA.

Need for Surveillance

- Asia is the region most targeted by cyber-attackers, resulting in significant economic losses. As the region continues to play a key role in the global economic market, these cyber threats are expected to increase. Over 460 million people in India currently use the Internet, leaving them vulnerable to online criminals – both individuals and organised syndicates.

Way Ahead

- The government has decided to hire IT experts from premier public and private institutes, including IITs, to help fight new age crimes like online fraud, hacking, identity theft, dark net, trafficking, child pornography, online radicalisation and cyber-terrorism and prepare a roadmap for Indian Cyber Crime Coordination Centre.

13.2 BLOCKCHAIN TECHNOLOGY

Blockchain is an online registry of digitally verified dealings, which is encoded in the blocks form, each of which is linked by a computers network.

They are ***a new data structure that is secure, cryptography-based and distributed across a network.*** The ***technology supports cryptocurrencies such as Bitcoin, and the transfer of any data or digital asset.*** Spearheaded by Bitcoin, blockchains ***achieve consensus among distributed nodes, allowing the transfer of digital goods without the need for centralised authorisation of transactions.***

How does it Operate?

1. The technology allows transactions to be simultaneously anonymous and secure, peer-to-peer, instant and frictionless.
2. It does this by distributing trust from powerful intermediaries to a large global network, which through mass collaboration, clever code and cryptography, enables a tamper-proof public ledger of every transaction that is ever happened on the network.
3. A block is the 'current' part of a blockchain which records some or all of the recent transactions, and once completed, goes into the blockchain as permanent database.
4. Each time a block gets completed, a new block is generated. Blocks are linked to each other (like a chain) in proper linear, chronological order with every block containing a hash of the previous block.
5. As a public ledger system, blockchain records and validates each and every transaction made, which makes it secure and reliable.
6. All the transactions made are authorised by miners, which makes the transactions immutable and prevent it from the threat of hacking.
7. Blockchain technology discards the need of any third-party or central authority for peer-to-peer transactions.
8. It allows decentralisation of the technology.

Benefits of Blockchain Technology

- In terms of a public ledger system, Blockchain account and authenticate each and every made transaction, thereby making it safe and dependable.
- All the done transactions are endorsed by miners, which make them absolute and avoiding it from the hacking risk.
- Blockchain Technology rejects any third-party or central authority requirement for peer-to-peer transactions.
- It allows technology decentralisation.

Usage of Blockchain in Public Administration

- Blockchain has the potentiality of optimising the public services delivery; further country's fight against corruption and produce ample citizen's value.
- Blockchain generates a proficient and cost-effective database that is practically tamper-proof, by preserving an absolute and chronological planned record of all actions and files ('blocks') associated together ('chain') in a circulated and decentralised database. By executing this, it undertakes building more clear, liable and able governments.
- In addition to this, Blockchain can also assist in building a more honest government. A public Blockchain, similar to Bitcoin usage, reports all information and transactions on the decentralised database permanently, publicly and most important of them securely. Blockchain can hold state and local actors answerable for any embezzlement, by permitting governments for tracking the government funds movement.
- Blockchain not only dissuades corruption with the help of accountability but it can also undertake so by entirely evading the middleman.

The West Bengal government has been preparing for introduction of blockchain technology for safeguarding its documents from cyber-attacks. The state government's planned Cyber Security Centre of Excellence would be assigned in executing the new 'blockchain' system at various departments. In July 2023, Airchains has partnered with New Town Kolkata Development Authority (NKDA) to enable blockchain-based tracking and recording of land mutations to enhance efficiency and security.

The cyber security centre will fetch the best in academic, law enforcement and other sections under single roof for undertaking the finest practices for countering Cybercrimes. The centre will also undertake research.

In 2017, computers at a few offices of the West Bengal State Electricity Distribution Company Limited were disabled by 'WannaCry' virus, a global ransomware. Ransomware is a kind of malicious software intended to block computer system access till the asked sum of money is paid.

Note: The **Tech Mahindra** and the Government of **Telangana** have signed an accord for establishing a country's first Blockchain district in Hyderabad, a first of its kind Centre of Excellence for Blockchain.

Possibilities of Blockchain are

- Confidential communication of cryptocurrency.
- Safe, cost-effective and fast bank transactions.
- Secure legal documents, health data, notaries and personal documents.
- Distribution of land records and government financial assistance.
- Cloud storage, digital identification, smart communication and digital voting.

National Informatics Centre (NIC) has set up a Centre of Excellence (CoE) in ***Blockchain Technology*** in Bengaluru, which will provide Blockchain as a service and allow stakeholders to benefit from shared learning, experiences and resources.

Functions

1. The Centre of Excellence will facilitate various government departments in building proof of concepts for use of Blockchain technology in different dimensions of governance, leading to large-scale deployment of some such applications.
2. With National Informatics Centre (NIC) providing a robust and an agile infrastructure, the CoE shall also provide Blockchain as a Service (BaaS) for efficient hosting of Blockchain network, says an official release.

Regulation in India

- The current debate in India has, unfortunately, focussed too heavily on trading and speculation, looking at cryptocurrencies as an investment tool, rather than understanding ***the potential of core blockchain technology and the basic role of cryptocurrencies as an incentive mechanism to secure decentralised transactions.***
- Prevailing cyber laws in India touch almost all aspects of transactions and activities involving ***the Internet, www and cyber space (IT Act, 2000 and amended in 2008, section 463 of IPC and section 420).*** But in today's techno-savvy environment the world is becoming more and more digitally sophisticated and so are the crimes. India's cyber laws are lacking in this respect.
- There are sufficient global examples of countries that have taken cautious steps in regulating the technology and are focussing on stopping illegal activity without hurting innovation.

RANSOMWARE CASE WORLDWIDE

WannaCry is a ransomware worm that spread rapidly through, across several computer networks in May of 2017. After infecting a Windows computer, it encrypts files on the PC's hard drive, making them impossible for users to access, then demands a ransom payment in bitcoin in order to decrypt them.

Petya is a ransomware strain discovered in 2016 that infects Microsoft Windows-based computers. Like other forms of ransomware, Petya encrypts data on infected systems. The data is unlocked only after the victim provides the encryption key, usually after paying the attacker a ransom for it.

Eternalblue allowed the ransomware to gain access to other machines on the network. On May 12, 2017, the worldwide WannaCry ransomware used this exploit to **attack** unpatched computers.

13.3 CRYPTOCURRENCY AND REGULATION OF OFFICIAL DIGITAL CURRENCY BILL, 2021

The Budget session of Parliament is likely to consider this Bill, which prohibits all private cryptocurrencies and provides for **an official digital currency to be issued by the Reserve Bank of India.**

The purpose of the law has been described as:

1. To create a facilitative framework for an official digital currency issued by the RBI.
2. To 'prohibit all private cryptocurrencies in India'.

The Bill also seeks to prohibit all private cryptocurrencies in India, however, it allows for certain exceptions to promote the underlying technology of cryptocurrency and its uses.

INDIA AND CRYPTOCURRENCY

2009: First cryptocurrency, Bitcoin launched in 2009 by Satoshi Nakamoto.

2018: RBI banned banks and other regulated entities from supporting crypto transactions.

2019: Inter-ministerial committee recommended banning all private cryptocurrencies.

2020: SC struck down the ban on the trading of cryptocurrency as unconstitutional.

2021: Cryptocurrency and Regulation of Official Digital Currency Bill, 2021 introduced.

Under this, a plan to ban private digital currencies favours RBI backed currency.

A 3-6 month exit period prior to banning the trading, mining and issuing of cryptos.

Finally, Cryptocurrencies, though unregulated, are not illegal in India.

ground

The Supreme Court, set aside on April 6, 2018, circular of the Reserve Bank of India (RBI) that prohibited banks and entities regulated by it from providing services in relation to Virtual Currencies (VCs).

What did the Court Say?

1. RBI has not come out with a stand that any of the entities regulated by it namely, nationalised banks/scheduled commercial banks/cooperative banks/NBFCs, have suffered any loss or adverse effect directly or indirectly, on account of Virtual Currencies (VCs).
2. Hence, the RBI circular is 'disproportionate' with an otherwise consistent stand taken by the central bank that VCs were not prohibited in the country.
3. Besides, the court found that the RBI did not consider the availability of alternatives before issuing the circular.
4. Besides, the court referred to the Centre's failure to introduce an official digital rupee despite two draft Bills and several committees.

What are Cryptocurrencies?

Cryptocurrencies are digital currencies in which encryption techniques are used to regulate the generation of units of currency and verify the transfer of funds, operating independently of a central bank.

Examples: Bitcoin, Ethereum, etc.

13.4 TOOLKIT

A toolkit has become a handy tool in sustaining a movement or campaign in times of social media influences.

- It is a document created as an explainer on an issue as a guide to everybody who is associated with the campaign or can be roped in to give a fillip to the campaign.
- It also provides a roadmap of how to take forward the campaign or agitation explaining what needs to be done, when and how.

13.5 CYBER INSURANCE

The policy provides protection in case of theft of funds due to **cyber** event/hacking of **insured** bank account/credit card/debit card/mobile wallet **by** a third party. It also provides protection in terms of defence costs for claims made against the **insured by** the third or affected party to identity theft fraud.

Cyber insurance for individuals policies are designed to cover expenses related to post factor actions of a cyber-attack, such as the cost incurred during the prosecution process and defence costs are paid by the insurance company relating to the types of cyber risks mentioned in the documentation of the policy.

Other costs such as financial losses, online loss of money suffered by the policyholder due to cyber-attacks are also covered in the policy up to the sum assured as mentioned in the policy. Expenses incurred for counselling treatments post a cyber-attack is also paid for including damages against third-party liabilities and restoration costs. It also takes care of consultant fees, court expenses and legal fees concerning the cyber-attack.

If the attack was intentionally and deliberately done, the policy will not pay any claim. Insurers do not cover any fraudulent, dishonest or malicious act. These policies do not provide any cover for any prior actions of the attack that the policyholder has faced before buying the policy; nor do they cover for personal data or lost pictures in the policy. The insurers also take measures to avoid any cyber-attack to their customers by prompting for backing up their data, updating anti-virus and having a proper set of passwords. If such measures are not taken properly, in case of a cyber-attack, your claim can be jeopardised.

13.6 WHATSAPP'S NEW POLICY BEING EXAMINED BY GOI

The Central government has informed the Delhi High Court that it was examining WhatsApp's controversial new privacy policy, which is scheduled to come into effect from 15 May, 2021, at the highest level.

Issue

The court was hearing a petition claiming that WhatsApp's new privacy policy violates ***the right to privacy*** *guaranteed under the Constitution.*

- The plea said the new policy 'virtually gives a 360-degree profile into a person's online activity' without there being any supervision of the government.
- The plea sought direction to issue guidelines to ensure such change in privacy policy by WhatsApp are carried out.

Key Features of the Policy

1. **Information Sharing with Third-Party Services:** When users rely on third-party services or other Facebook Company Products that are integrated with the services, those third-party services may receive information about what someone or others share with them.
2. **Hardware Information:** WhatsApp collects information from devices such as battery level, signal strength, app version, browser information, mobile network and connection information (including phone number, mobile operator or ISP), among others.
3. **Deleting the Account:** If someone only deletes the WhatsApp app from their device without using the in-app 'delete my account' feature, then that user's information will remain stored with the platform.
4. **Data Storage:** WhatsApp mentions that it uses Facebook's global infrastructure and data centres including those in the United States to store user data. It also states that the data in some cases will be transferred to the United States or other parts where Facebook affiliated companies are based.
5. **Location:** Even if a user does not use their location-relation features, Whatsapp collects IP addresses and other information like phone number and area codes to estimate one's general location (city, country).
6. **Payment Services:** WhatsApp says if anyone uses their payment services, they will process additional information about a person including paymen account and transaction information.

Centre Moved Court over WhatsApp's New Privacy Policy

The Ministry of Electronics and Information Technology has asked the Delhi High Court to step in and restrain WhatsApp from rolling out its new privacy policy.

Why does the IT Ministry want the High Court to Restrain WhatsApp?

Supreme Court judgements had placed a responsibility upon the Centre to come out with a 'regime on data protection and privacy', which would 'limit the ability of entities' such as WhatsApp to issue 'privacy policies which do not align with appropriate standards of security and data protection'. Therefore, WhatsApp must be stopped from rolling out the services.

The IT Ministry has listed major violations of the current IT rules that the new privacy policy of WhatsApp, if rolled out, could entail. They are:

1. WhatsApp failed to specify the type of sensitive data being collected by it.
2. WhatsApp has failed to provide the user an option to review or amend the users' information being collected by it.
3. The policy fails to provide users an option to withdraw consent on data sharing retrospectively.
4. It also fails to guarantee non-disclosure by the third parties.

Other Issues and Concerns

1. The new Whatsapp policy contradicts the recommendations of **the Srikrishna Committee Report,** which forms the basis of the Data Protection Bill, 2019.
2. The principle of **Data Localisation,** which aims to put curbs on the transfer of personal data outside the country, may come in conflict with WhatsApp's new privacy policy.
3. With the updated privacy policy, **WhatsApp can now share one's metadata, essentially everything** beyond the conversation's actual text.
4. **If users disagree with the messaging platform's updated privacy policy,** they will have to quit WhatsApp when the new terms of service are set to come into effect.

SANDES

- The National Informatics Centre has launched an instant messaging platform called Sandes on the lines of WhatsApp.
- Like WhatsApp, the new NIC platform can be used for all kinds of communications by anyone with a mobile number or email id.
- The limitation, however, is that the app does not allow the user to change their email id or registered phone number. The user will have to re-register as a new user in case they wish to change their registered email id or phone number on the app.

13.7 CYBERDOME

Cyberdome is a pioneering **project** as it brings together Government Departments, Law Enforcement Agencies, Industry, Academia, International Organizations and experts from the public domain for collaborating on cyber security to enhance the capabilities of the state in dealing with cyber threats.

Cyberdome is technological research and development Centre of Kerala Police Department. It aims to meet the long-term security challenges of bridging the gap between the latest innovations in the **cyber** space and the skill set of Kerala Police, in combating the emerging **cyber** threats.

Work of Cyberdome

- Child pornography pages have been removed.
- Movie piracy has been stopped by blocking the websites.
- Tracking system developed by the team to identify the location from where data is sent.
- During Ransomware attack in 2017, it also protected lot of computers in Kerala against cyber threat.

In 2018, Assam government launched Assam Police Cyberdome and Digital Intelligence and Training and Analysis Centre (DITAC) in Kahilipara, Guwahati.

Thus, Cyberdome project can be termed a unique experiment in our current administrative system. Success of this project depends on its implementation. There are chances to expand this project to include other parts of our governance system too.

13.8 SPYWARE-PEGASUS

Spyware refers to malicious software or programs that are designed to covertly gather information about a user or their activities without their knowledge or consent.

(Refer **Infographic - Spyware, Pegasus, Cryptojacking and Bluebugging**)

13.9 CRYPTOJACKING

Cryptojacking is the act of hijacking a computer to mine cryptocurrencies against the user's will, through websites, or while the user is unaware.

(Refer **Infographic - Spyware, Pegasus, Cryptojacking and Bluebugging**)

13.10 BLUEBUGGING

Bluebugging is a type of malicious attack that allows hackers to gain access to your Bluetooth-enabled devices. Bluebugging is conducted by exploiting a security flaw in the Bluetooth protocol.

(Refer **Infographic - Spyware, Pegasus, Cryptojacking and Bluebugging**)

SPYWARE

WHAT IS A SPYWARE?

- Spyware refers to malicious software or programs that are designed to covertly gather information about a user or their activities without their knowledge or consent. It is a type of malware (malicious software) that is often installed on a computer or mobile device without the user's awareness.
- Spyware can monitor a user's online activities, such as websites visited, keystrokes typed, login credentials entered, and even capture screenshots or video recordings. It may also track other sensitive information like personal data, banking details, or browsing habits. The collected data is typically sent to a remote server or third-party without the user's consent, where it can be exploited for various purposes, such as targeted advertising, identity theft, or unauthorized surveillance.
- Spyware can be distributed through deceptive tactics, including email attachments, software downloads from untrusted sources, malicious links, or bundled with legitimate software. Once installed, it operates silently in the background, often evading detection by antivirus or security software.

WHAT IS PEGASUS SPYWARE?

Pegasus is a sophisticated spyware developed by NSO Group.

Controversy surrounds its use, including alleged targeting of journalists, activists, and dissidents.

Pegasus has been associated with government and state-sponsored surveillance.

The collected data is transmitted to a remote server for analysis.

It targets mobile devices, including IOS and Android smartphones.

Pegasus is advanced spyware that can infiltrate devices silently, using "zero-click" or "nearly zero-click" techniques, requiring minimal or no interaction from the user.

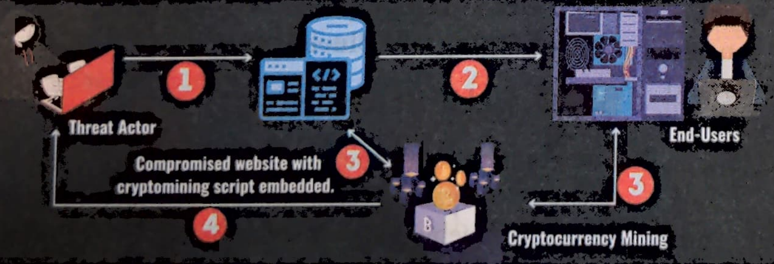
Once installed, Pegasus gains complete access to device contents.

It can monitor calls, messages, emails, and collect data like photos and location information.

Pegasus can activate the device's microphone and camera for real-time surveillance.

WHAT IS A CRYPTO JACKING (MALWARE)?

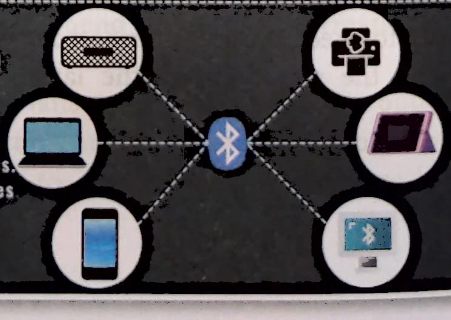
- Cryptojacking involves hijacking someone else's computer or device for unauthorized cryptocurrency mining.
- Attackers exploit vulnerabilities or use malicious techniques to infect systems with mining malware.
- The malware runs in the background, utilizing the device's resources for mining operations.
- Profits from mining go to the attacker, while the owner experiences performance issues and increased costs.
- Infection can occur through malicious downloads, infected websites, or phishing emails.
- Protection involves keeping software updated, using reputable security software, and being cautious online.
- Monitoring system performance helps detect signs of excessive resource usage.



① The threat actor compromises a website.
② Users connect to the compromised website and the crypto mining script executes.
③ Users unknowingly start mining cryptocurrency on behalf of the threat actor.
④ Upon successfully adding a new block to the blockchain, the threat actor receives a reward in cryptocurrency coins.

WHAT IS A BLUEBUGGING (HACKING) ?

- Bluebugging targets Bluetooth-enabled devices.
- It exploits Bluetooth vulnerabilities for unauthorized access and control.
- Attackers can make calls, send messages, or access data without the owner's knowledge.
- It may allow eavesdropping or monitoring of activities.
- Keep Bluetooth off when not in use and update devices for protection.
- Be cautious of untrusted Bluetooth connection requests.



14.1 COMPUTER

Computer is a combination of two words 'compute' and 'er'. **'Compute' means calculation and 'er' means device. Computer is an electronic device. It can perform all types of mathematical and logical operations. It can accept data, store data, process data, retrieve data and print data.**

14.2 HISTORY OF COMPUTER

The ***Abacus* Idea** was first introduced between 1000 BC and 500 BC. A series of moveable beads or rocks were used in the apparatus. The positions of these beads were changed while entering a number and again to perform mathematical operations.

The Abacus or counting frame serves as a calculating tool used in primarily parts of Asia for performing arithmetic calculations. It is made of beads or stones placed in grooves or strung on rods. *Abacus* is a Latin word which originated from the Greek word abax or abakon (meaning 'table' or 'tablet'). The Chinese invented it around 2600 B.C. Leonardo da Vinci may have conceived the world's first mechanical calculator around 1502. **In 1834, Charles Babbage introduced analytical engine and showed it at the Paris Exhibition in 1855.**

TYPES OF COMPUTERS

.1 On the Basis of Function

On the basis of function, computers are divided into three parts:

1. **Analogue Computer:** In analogue computers, numerical data are represented by measurable physical variables, like electrical voltage, pressure, temperature, etc. For instance, a thermometer is a simple analogue computer, where mercury moves with variation in temperature.
2. **Digital Computer:** A computer that accepts and processes data in the form of numbers (0–9) and characters (A–Z) that has been converted into binary code. Most of the computers are digital.
3. **Hybrid Computer:** The feature of analogue and digital machines is combined to create hybrid computers.

14.3.2 On the Basis of Processing Speed and Storing Capacity

On the basis of processing speed and storing capacity, computers are divided into four parts:

1. **Microcomputers:** Microcomputers known as personal computers (PC). It has lowest storing and processing speed. It is designed to be used by individuals.
2. **Mini Computers:** Mini computers are more powerful computers as compared to microcomputers. It has high memory and processing speed and can be used as server. A minicomputer is a multiprocessing system, which can support 4 to 200 users at the same time.
3. **Mainframe Computers:** A mainframe computer is different from micro and mini. It has very high memory and processing speed and is used as server (can support thousands of users). A mainframe is high-performance computer that is used for large-scale computing purposes.
4. **Supercomputers:** Supercomputer is a different type of computer and can be used for complex applications. Supercomputer is a powerful and high-performance machine used for mostly scientific computations. Cray-1 was the first supercomputer developed in 1976. Supercomputer is used for scientific research, weather forecasting, weapon designing, etc. India's first supercomputer PA RAM-10000 was developed by C-DAC, Pune. Other supercomputers are EKA, SAGA-220, Anurag, etc.

Note: Disk space, data storage space and system memory all are described on the basis of various parameter. Few years ago we were describing hard drive space using the term Megabytes, on the basis of data storage capacity. Today, Gigabytes and Terabytes are the most common terms being used to describe the size of a hard drive (**Table 14.1**).

Bit The term 'bit' is derived from phrase Binary Digit. A bit is single digit number base-2 (0 or 1). It is the smallest unit of computer data. About 16,000 bits are contained in a full page of text.

14.4 UNITS USED IN COMPUTERS TO STORE AND PROCESS DATA

TABLE 14.1 Units used in computers to store and process data

1 nibble	**4 bit**
1 byte	8 bit
1 kilobyte	1024 byte
1 megabyte	1024 kilobyte
1 gigabyte	1024 megabyte
1 terabyte	1024 gigabyte
1 petabyte	1024 terabyte
1 exabyte	1024 petabyte
1 zettabyte	1024 exabyte
1 yottabyte	1024 zettabyte

14.5 USES OF COMPUTER IN DIFFERENT DISCIPLINES

- Computers have *become very popular in all fields. Here are some of areas where they are widely used.*
- **Education:** Computers give students more flexibility with their studies. Computers are also used by teachers to prepare lessons, report card and as reference tools.
- **Medicine:** A large number of computerised equipment are used for medical tests in hospitals and clinics. They can be used for storing medical records of patients visiting big hospitals. Doctors can access these records of patients to diagnose.
- **Business:** Every company or organisation requires computers for budgeting, accounting, billing, reporting, presentations, etc. This information must be constantly maintained and updated. Computers are also used for sales forecasting, production, planning, etc.
- **Science and Technology:** Scientists and Engineers use computers as a tool to experiment, design and develop their ideas/projects. Architects use computers to design structures. Nuclear tests can be simulated without damaging the environment. Hence, the more popular forms of today's time are Computer-Aided Designing (CAD) and Computer-Aided Engineering (CAE).
- **Communication:** Many offices and homes have computers and hence, the sharing of data and programmes among various computers needs to be in accordance with the advancement of data-communication facilities. Using Internet facility, you can send e-mail to your friends and relatives.
- **Banking:** Computers are being used in banks for carrying out everyday transactions like online enquiry of customers' balance, cheque verification, updating of balance, calculating interests, etc. All progressive banks have installed Automated Teller Machines (ATM) to enable the customers to withdraw money from their accounts, money transfer, etc.
- **Weather Forecasting:** Data are collected from weather stations and satellites all over the world. Changes in weather and direction of winds can be analysed with the help of computers. Timely prediction may avoid damage due to natural disasters.
- **Entertainment:** Through computers, you can play various games, create your own music, watch cartoons or films, listen to your favourite music, etc. Cartoon films are created very easily through computer animation. Special effects like fire, battle, earthquake, etc., can be created for films.
- **Defence:** In defences, computers can be very useful. Modern weapons and missiles are totally computer-controlled.

14.6 CHARACTERISTICS OF THE COMPUTER SYSTEM

The characteristics of the computer system are as follows:

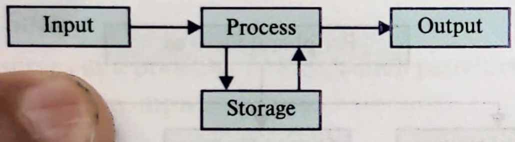
- **Speed:** A computer works with much higher speed and accuracy compared to humans while performing mathematical calculations. Computers can process millions (1,000,000) of instructions per second. The time taken by computers for their operations is microseconds and nanoseconds.
- **Accuracy:** Computers perform calculations with 100% accuracy. Errors may occur due to data inconsistency or inaccuracy.
- **Diligence:** A computer can perform millions of tasks or calculations with the same consistency and accuracy. It doesn't feel any fatigue or lack of

concentration. Its memory also makes it superior to that of human beings.

- **Versatility:** Versatility refers to the capability of a computer to perform different kinds of work with same accuracy and efficiency.
- **Reliability:** A computer is reliable as it gives consistent result for similar set of data, i.e., if we give same set of input for any number of times, we will get the same result.
- **Automation:** Computer performs all the tasks automatically, i.e., it performs tasks without manual intervention.
- **Memory:** A computer has built-in memory called primary memory where it stores data. Secondary storage are removable devices such as CDs, pen drives, etc., which are also used to store data.

14.7 BASIC STRUCTURE OF A COMPUTER SYSTEM

Computer follows input + process + output cycle (IPO CYCLE) in order to perform a task (**Figure 14.1**).



ructure of Computer System

IPOS Cycle It is how computer intakes data, processes the data, outputs information and then saves the information. I stand for input, P stands for processing, O stands for output and S stands for storage.

Input Input is the raw data, entered into a computer from the input devices. It is the collection of numbers, letters, images, etc. Keyboard, mouse, scanner, webcam, etc., are some examples of the input devices.

Process Process is a total internal process, which represents the operation of data or information as per given instruction. The main processing device of the computer is the CPU (Central Processing Unit).

Output The result of processed data is given in the form of 'output', post data processing. We can save these results in the storage devices for the future use. Monitor, printer and speaker are the main output devices.

14.8 DATA REPRESENTATION COMPUTER

Most Computers are Digital

- Computer recognises only two discrete states: On or Off (**Figure 14.2**).
- Computers are electronic devices powered by electricity, which has only two states, On or Off.

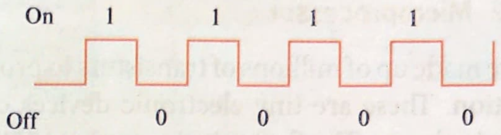


Figure 14.2
Digital Signals

Data in computers are represented in binary form. To understand data representation, one has to know four number system.

1. **Decimal number system:** In this system we use ten different symbols to represent any number. Therefore, its base is ten. Following are the symbol used in this system. 0, 1, 2, 3, 4, 5, 6, 7, 8, 9.
2. **Binary number system:** In this system, we use only two symbols, i.e., 0 and 1. Therefore, its base is two.
3. **Octal:** In this system eight symbols are used, i.e., 0, 1, 2, 3, 4, 5, 6, 7. Therefore, its base is eight.
4. **Hexadecimal:** In this system sixteen symbols are used 0123456789 ABC DE F. Therefore, its base is 16.

14.9 COMPONENTS OF COMPUTER SYSTEM

A computer consists of two basic components: (1) Hardware and (2) Software.

14.9.1 Hardware

The entire physical components that are grouped together and form a complete system are known as hardware, e.g., PC-Case, motherboard, RAM, ROM, hard disk, monitor, keyboard, mouse, etc.

Hardware is divided into three parts:

1. CPU
2. Memory Unit
3. Peripheral Device

14.9.1.1 Central Processing Unit

It is known to be the brain of a computer system. It is also named as microprocessor, when constructed on a single chip. A complete CPU consists of Arithmetic Logic Unit (ALU) and control unit along with registers. The input/output unit, CPU and memory unit together constitute a computer system.

14.9.1.2 Microprocessor

They are made up of millions of transistors to process the instruction. These are tiny electronic devices carrying an electric charge. **The first microprocessor 4004** (4 bit microprocessor) **was invented by INTEL in 1971.** It was designed for specific applications. The first general purpose microprocessor 8008 was introduced in 1974 which was 8 bit microprocessor. Currently, 32/64-bit processors are available in the market.

Note: All processors are not CPUs but all CPUs are known as microprocessors. The CPU controls all the components of the computer system, while the function of a processor is to process, the instruction.

14.9.1.3 Control Unit

The flow of information within the computer system is controlled by Control Unit. It functions as in-charge of the computer as it decodes machine instructions and generates control signal. It may also control some external devices.

14.9.1.4 ALU (Arithmetic Logic Unit)

The arithmetic and logical operations of the computer are performed by arithmetic/logic unit (ALU).

14.9.1.5 Memory Unit

It serves as the main memory, also known as primary memory or semiconductor memory. It is an internal memory, which includes the following two parts:

1. RAM (Random Access Memory)

It is a 'read and write' memory, which is a volatile and temporary memory. Two types of RAM are as follows:

1. **Static RAM:** It is called so since it continues to hold information without refreshment and does not need to refresh.
2. **Dynamic RAM:** It is called dynamic as refreshment is required and it loses information with time.

2. ROM (Read Only Memory)

Read only memory is non-volatile and hence, permanent in nature. With ROM, the data and instruction can only be read and the user is not allowed to write anything on it. The manufacturer writes the contents of ROM at the time of manufacturing.

3. Flash Memory

Flash memory, like ROM, is non-volatile memory. However, it is an integrated circuit with no continuous power requirement to retain the data. Flash memory is comparatively more expensive than magnetic storage. However, flash memory is widely used with car radios, cell phones, digital cameras, PDAs, MP3 players and printers.

14.9.1.6 Peripherals Device

The input device, output device, storage device, communication device or other functions under the direct control of a computer, altogether constitute auxiliary equipment or peripheral devices (**Figure 14.3**).

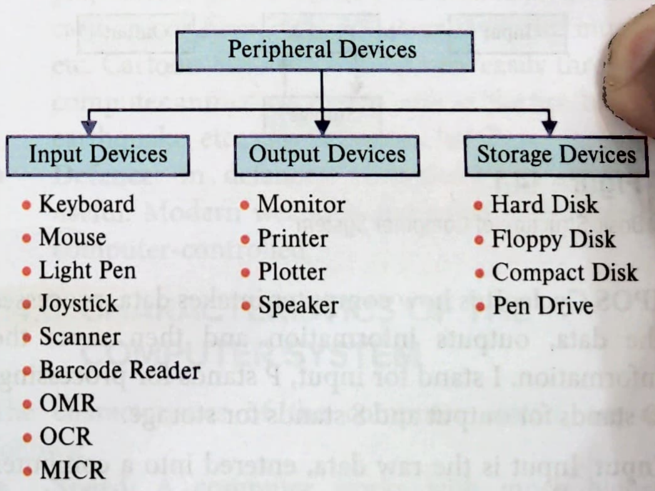


Figure 14.3
Outline of Peripheral Device

1. Input Device

It is a computer hardware or device that can accept data or instructions. Examples include **keyboard, scanner, mouse, joy stick, bar code reader, microphone,** etc.

2. Output Device

It is a computer hardware or device which displays the result or output of the processed data. Examples include **monitor** (VOU), **printer, plotter, speaker,** etc.

3. Storage Device

A computer hardware device that stores information permanently, hence, also called secondary memory, e.g., **hard disk, floppy disk, compact disk, pen drive,** etc.

4. Communication Device

- **Microphone, modem and router**

5. Keyboard

It serves as standard input device. Keyboard was introduced with 84 numbers of keys. Now-a-days, minimum number of keys present on keyboard is 101 keys.

6. Mouse

It serves as a standard pointing device. Mouse can only be used in GVI. Douglas Engelbart invented it in 1963.

7. Light Pen

It is another pointing device, used for digital signature. A light pen only works with CRT-based monitor and not with LCD screens, projectors or other display devices.

8. Joy Stick

It also serves as a pointing device, which provides better control during computer games.

9. Scanner

A scanner enables to capture documents or pictures, which are in printed form on paper. After capturing, they are turned into digital format to be viewed on a computer.

10. Microphone

A microphone serves to input sound information. We can record sound and voice to place it onto the computer via microphone.

11. Barcode Reader

The different groups of vertical bars are known as Barcodes and to read them on a computer, we need a barcode reader. Today we can find barcodes printed on nearly every product available in the market.

14.9.1.7 Output Device

1. Monitor

The standard output device (**Figure 14.4**) is known as monitor. Another name for monitor is visual display unit. It displays the computer's user interface and opens programmes, thus, enabling the user to visualise the inputs.

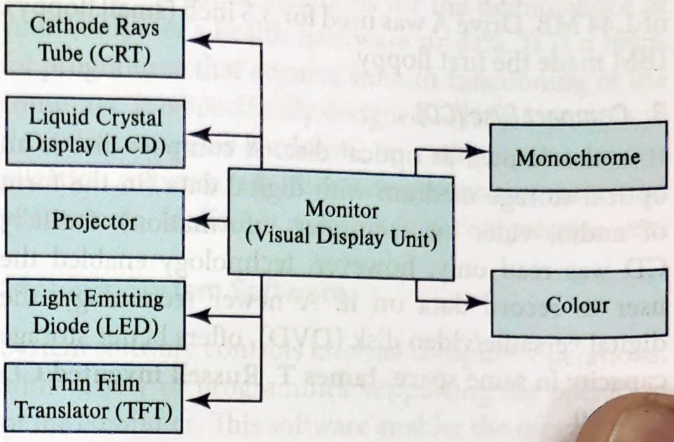

Cathode Rays Tube (CRT)
Liquid Crystal Display (LCD)
Projector
Light Emitting Diode (LED)
Thin Film Translator (TFT)
Monitor (Visual Display Unit)
Monochrome
Colour

Figure 14.4
Various Output Devices

2. Printer

Printer prints text or image on paper, hence, it is an output device. The output given out by the printer on a paper is called a hard copy. Printers are of two types:

1. **Impact Printer:** The oldest printer still in action is known as impact printer. With this type of printer, a character is formed when something strikes the paper and ribbon together. Examples include dot matrix printer, chain printer, etc.
2. **Non-Impact Printer:** They do not involve striking the paper. Rather, they use ink spray or toner powder to form the character.

14.9.1.8 Storage Device (Secondary Memory)

1. Hard Disk

It is a magnetic disk on which you can store computer data. Hard disk is a magnetic disk, which serves as the computer's main storage device. In terms of storage capacity and speed, it is better than other storage devices. On 13 September 1956, the hard drive was first introduced.

2. Floppy Disk

A small portable magnetic disk used to store and transport computer data is known as floppy disk or a diskette. Floppy disk is of two types. In 1978, a 5.25-inch disk was introduced, with storage capacity of 360 KB of data. Later revisions of the 5.25-inch floppy disk was developed which could store 1.2 MB. Drive B was used for 5.25-inch floppy. In 1987, the 3.5-inch HD (High Density) floppy disk was released, with storage capacity of 1.44 MB. Drive A was used for 3.5 inch (small floppy). IBM made the first floppy.

3. Compact Disc (CD)

It is also known as optical disc. A compact disc is an optical storage medium with digital data (in the form of audio, video or computer information). Initially CD was read only, however, technology enabled the user to record data on it. A newer technology, the digital versatile/video disk (DVD), offers better storage capacity in same space. **James T. Russell invented CD in 1960.**

4. Pen Drive

Pen drive represents small portable USB flash drive. It consists of flash memory data storage device integrated with USB. A plug and play device or pen drive is known with different names such as USB flash drive, jump drive, thumb drive, etc. Dov Moran introduced and invented USB Flash Drive in 1996.

Note: Direct Access Devices: Hard disk, Floppy disk, Compact disk, etc.

14.9.1.9 Primary Memory (RAM)

1. Disk Cache

It is used between hard disk and main memory. Its main objective is to reduce the speed gap between main memory and hard disk. It is logically created inside the disk.

2. Cache Memory

The fastest and most expansive memory is Cache, which increases the efficiency of central processing unit and lies between CPU and main memory. The cache memory is used by CPU to store repeatedly required instructions, while running a programme. Additionally, it improves system speed. The cache memory is advantageous since the CPU does not have to use the motherboard's system bus for *data* transfer.

The *data* frequently used by CPU is instantly available via cache. A fetch is made from the main memory, only if the required information is not located in the cache.

The performance of cache memory is frequently major in terms of quantity called hit ratio. When CPU refers to memory to find the words in cache, it is 'HIT'. If the word is not found in cache, it is in main memory, then it is counted as a 'Miss'.

3. Virtual Memory

When the space on a Hard Disk Drive (HDD) is used to simulate additional main memory, it is termed as virtual memory. It allows software (with greater size than computer's RAM) to run in a memory space (i.e., a logical memory). In other words, if your computer lacks the RAM required for running a programme or operation, virtual memory helps windows to compensate.

14.9.1.10 Generation of Computer (Hardware)

The development of computer through different generations is detailed in **Table 14.2** as follows:

TABLE 14.2 Different Generation of Computer System

Generation of Computer	Hardware
First-Generation (1940–1956)	Vacuum Tube
Second-Generation (1956–1963)	Transistors
Third-Generation (1964–1970)	IC (Integrated Circuit)
Fourth-Generation (1971–Present)	LSI (Large-Scale Integration), VLSI (Very Large-Scale Integration), ULSI (Ultra Large-Scale Integration)
Fifth-Generation (Today)	Still under development phase

Note: Today's computers are the fifth-generation computers. This generation is based on parallel processing hardware and AI (Artificial Intelligence) software. AI is an emerging branch in computer science, which interprets the means and method of making computers think like human beings. All the high-level languages like C and C++, Java, .Net, etc., are used in this generation.

Artificial Intelligence is also known as knowledge information processing system.

Generation of Computers

C – Common
O – Operating
M – Machine
P – Purposely
U – Used for
T – Technological
E – Educational
R – Research

14.9.2 Software

Software It is a set of programmes which can be developed by a software programmer with the help of computer language and a set of instructions.

Software is classified into three categories as discussed below:

1. Application software
2. Utility software
3. System software

14.9.2.1 Application Software

Application software is a computer programme designed to help the user performing a certain type of task. These softwares are written or developed by a programmer for enabling the computer to perform specific tasks such as processing words, handling calculations, etc.

14.9.2.2 Utility Software

A utility programme functions for the maintenance of your computer's health hardware or data. It is a helpful programme that ensures smooth functioning of the computer. It is specifically designed to help manage and time the computer hardware, operating system or application software, e.g., disk defragmentation, antivirus programme, file/folder management, compression, etc.

14.9.2.3 System Software

System software controls internal computer operations, with variety of programmes supporting the operation of the computer. This software enables the user to focus

4.3 19th Century Computers

	First-Generation Computers	Second-Generation Computers	Third-Generation Computers	Fourth-Generation Computers	Fifth-Generation Computers
Year	1942–1954	1952–1964	1964–1972	1972–1989	1989–Present
Technology	Vaccum Tubes	Transistors	Integrated Circuits with SSI and MSI technology	Integrated Circuits with VLSI technology	Integrated Circuits with ULSI technology
Memory	Electromagnetic relay memory	• Magnetic cores memory • Magnetic tapes	Larger magnetic cores	Microprocessor semiconductor memory	Large-Scale Microprocessor semiconductor memory
Storage	Punched Cards	Disks	Larger capacity disks and magnetic tapes	• Larger capacity disks • Magnetic tapes and floppy disks	Larger capacity portable disks and optical disks
Computer Names	1. ENIAC 2. EDSAC 3. EDVAC 4. UNIVAC 5. IBM – 701 6. IBM – 650	1. IBM – 1620 2. IBM – 7094 3. CDC 1604 4. CDC 3600 5. UNIVAC 1108	1. IBM – 360 series 2. Honeywll 6000 series 3. PDP (Personal Data Processor) 4. IBM – 370/168 5. TDC – 361	1. DEC 10 2. STAR 1000 3. PDP 11 4. CRAY – 1 5. CRAY – X – MP	1. Desktop 2. Laptop 3. Notebook 4. Ultrabook 5. Chromeebook
Key Features	• Huge size • Highly unreliable • Very costly • Difficult to use • Not for commercial use • Consumed a lot of electricity • Generates a lot of heat so AC needed	• Smaller size in comparison to first-generation computers • Fast and reliable • Still very costly • Difficult to use • Not for commercial use • Consumes less electricity in comparison to first generation • Still generates heat so AC needed	• Small size • Faster and more reliable • Still costly • Lesser maintenance • Started for commercial use • Consumed lesser electricity • Generates less heat but AC required	• Very small size and portable • Very fast and much more reliable • Very cheap • Very less maintenance • Computers became easily available • No AC required	• Very fast and highly reliable • Availability of very powerful and compact computers at cheaper rates • More user-friendly interfaces with multimedia features • Advancement in super-conductor technology • Advancement in **Parallel Processing** • Development of artificial intelligence

on his tasks without caring how the machine works internally. For example, user operating system, linker loader, language processor, etc.

Operating System – A set of programmes that helps in controlling and managing the hardware and the software resources of a computer system is termed as operating system. It establishes the relationship between hardware and software. It gives the platform to run various softwares. It has three main responsibilities:

- Performs basic tasks including recognising input from the keyboard, sending output to the display screen and keeping track of files and directories on the disk. It also controls peripheral devices.
- Ensures that different programmes and users are running simultaneously and they do not interfere with each other.
- Provides a software platform to run other programme.

14.10 COMPUTER LANGUAGE

A computer language is the means by which instructions and data are transmitted to computers. Languages are divided into two categories:

14.10.1 Low Level Language

Machine Language In machine language, programmes can be developed in binary language (0 or 1). It is also known as binary language.

Assembly Language It is known as symbolic language. It is a low-level programming language using human readable instruction of the CPU. It is written as:

Move ab, cd
Move ax, 50

14.10.2 High Level Language

Programmer can write code in simple English language. It is very user friendly as compared to low-level language, e.g., C, C++, Pascal Fortran, COBOL, basic, prolog, java, etc.

Loader A set of programme that loads the machine language translated by the translator into the main memory and makes it ready for execution.

Linker The main purpose of linker is to link the external module or functions which are not defined in the given programme to the current running programme.

14.11 ANALOGUE AND DIGITAL TRANSMISSION

Analogue Signal An analogue signal (**Figure 14.5**) is continuous with respect to time and may take on any value within a given range of values. Analogue signals are produced when human voice, videos and music are converted to electrical signal using a suitable device. Analogue signal is used in landline phones.

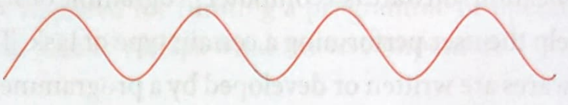


Figure 14.5
View of Analog Digital

Digital Signal Only a discrete set of values is taken by digital signal (**Figure 14.6**) within a given range. Most of the computers and computer-related equipments are digital.

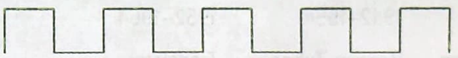


Figure 14.6
View of Digital Signal

14.12 DATA FLOW

Different forms of communication between two devices can be simplex (**Figure 14.7**), half-duplex and full-duplex (**Figure 14.8**).

- **Simplex:** It is one way data transmission, e.g., pager, radio and T.V.

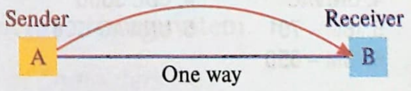


Figure 14.7
Simplex

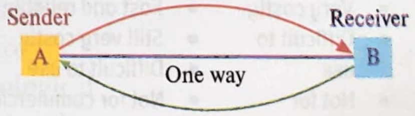


Figure 14.8
Duplex

Half-Duplex In half-duplex, each station can both transmit and receive but not simultaneously. The half-duplex mode resembles one-lane road with traffic allowed in both direction, e.g., Wireless, Walky-talky.

Full-Duplex In full-duplex mode, data can be transmitted and received at the same time. It is a simultaneous two-way data transmission, e.g., telephone, videoconferencing, etc.

14.13 LAN HARDWARE AND SOFTWARE

14.13.1 LAN Hardware: The Basic Hardware Components of LAN are

14.13.1.1 Transmission Channel

Four types of channels are used for data communication LAN. They are as follows: (1) Twisted pair cable, (2) Coaxial cable, (3) Fibre optics and (4) Radio waves.

14.13.1.2 Network Interface Unit (NIU)

It connects each device in the LAN network to shared transmission device. The LAN contained in NIU contains the rules and logic to access the LAN. Additional applications involve implementing LAN protocols and for device attachment. Its function depends on the type of topology used in LAN.

14.13.1.3 Servers

LAN is beneficial while sharing expensive resources such as storage devices, printer, etc. This is achieved through providing servers on LAN. It is dedicated to control one or more resources. Both hardware and software interface for LAN is contained in it. Three major categories of servers.

14.13.1.3.1 File Server

It shares storage space for files used for taking periodical backup and also provides gateway to other servers within and between LANs.

14.13.1.3.2 Printer Server

Printer server handles printing works of all workstations that are connected in the network.

14.13.1.3.3 Modem Server

In LAN environment also, we require modem for connection (or simply use a telephone) to other network. To share resource by all connected workstations in a network, we need a modem server.

14.13.1.4 Workstations

In a network, computers connected with servers to the main computer is known as workstation/terminal/client/slave.

14.13.2 LAN Software/Operating System

Main software of LAN is an operating system. It manages workload with number of various types of servers attached to it. It has two aspects (1) Server software and (2) Work station software. LAN operating system facilitates the sharing of expensive resources such as printer storage space, etc. There are various types of LAN operating systems. Such examples include Novel, Netware and Win N1: Win 2000 server, Unix, etc.

14.13.3 Metropolitan Area Network (MAN)

It is designed for a city or town. MAN, as a computer network, is smaller than WAN but larger than LAN.

14.13.4 Wide Area Network (WAN)

WAN covers large geographical area, e.g., different cities, states and countries. One LAN can be connected to other LAN over any distance via telephone and radio waves. A system of LANs so connected is called WAN.

14.13.5 WAN Devices: Bridges, Router

While searching a path between two computing devices that are to communicate and for forwarding the data packets on this path, a routing device is required. Bridges, router and gateway are some of the devices that provide this routing function.

Bridges Bridges connect two LANs using identical protocols over a wide area. The bridge acts as an address filter which picks up packets from one LAN to be transmitted to a destination on another LAN, and thereby, passing these packets on the network.

Router Routers may connect dissimilar networks. They provide connectivity between two LANs or two WANs over large geographical distances.

14.14 TERMINOLOGY

14.14.1 Node

Different terminals which are attached to the network and share the resources of the network are called nodes. In the network, the nodes are computers.

14.14.2 Server

A computer programme or software package provides a specific kind of service to client software that runs on other computers. A dedicated computer provides function to the network. A client is a computer which requires any of the resources provided by the server. The advantage of client/server model of computing is the control which can be exercised on the content of the server.

14.14.3 Workstation

It is that device which is deployed to communicate with data communication network. The workstation may be a terminal printer. In telephone or in other communication devices, workstation is called terminal client or slave.

14.14.4 Network

A way or means of transmission or receiving of information from one or more sources is termed as network.

14.14.5 Network Interface Unit

The interface which helps in the communication between the server and different nodes is called Network Interface Unit.

14.14.6 Architecture

The broader classification of network is either *via* a peer to peer or client/server Architecture.

QUESTIONS AND ANSWERS

15.1 DEFENCE

'Defence' for a country is protecting its integrity, maintaining sovereignty, protecting international borders, maintaining unity and protecting the geo-economic interests of the nation and not allowing any kind of threat to enter into the country through land, sea or air.

15.2 INDIAN DEFENCE

The supreme commander of the Indian defence system is the President of India. The whole administrative control of Armed Forces lies in **Ministry of Defence.** Indian Defence System has been divided into three services – Army, Air Force and Navy.

15.2.1 Indian Army

Indian Army is for defending territory of country and to neutralise any attack from other country. **It is the third largest Army of the World after China and USA,** has strength of 1.3 million active personnel. Indian Army operator has six operational commands and one training command.

(a) **Northern Command** – Udhampur
(b) **Western Command** – Chandigarh
(c) **Central Command** – Lucknow
(d) **Eastern Command** – Kolkata
(e) **Southern Command** – Pune
(f) **South-Western Command** – Jaipur
(g) **Training Command** – Shimla

15.2.2 Indian Air Force

Indian Air Force is to secure India, airspace and to neutralise any attack or aggression through air. Indian Air Force have 1,27,000+ active personnel. IAF have five operational commands, one training command and one maintaining command.

(a) **Eastern Command** – Shillong
(b) **Western Command** – New Delhi
(c) **Central Command** – Allahabad
(d) **Southern Command** – Thiruvananthapuram
(e) **South-Western Command** – Gandhi Nagar
(f) **Training Command** – Bangalore
(g) **Maintenance Command** – Nagpur

15.2.3 Indian Navy

Indian Navy is to protect territorial waters, coastal line and geo-political interests in different seas and oceans. It has strength of 58,000+ active personnel and status of Blue Water Navy. Indian Navy operator has three operational commands.

(a) **Eastern Command** – Vishakhapatnam
(b) **Western Command** – Mumbai
(c) **Southern Command** – Kochi

15.3 DEPARTMENTS UNDER MINISTRY OF DEFENCE

Ministry of Defence provides the policy framework and the execution of approved programmes within the allocated resources to the Department of Defence, Department of Defence Production, Department of Defence Research and Department of Ex-Servicemen.

15.3.1 Department of Defence

The integrated Defence Staff and their services and various inter-service organisations, along with defence budget, establishment matters, defence policy, parliament-related matters are dealt by the Department of Defence. Besides this, it also takes care of the co-operation of defence with foreign countries and co-ordination of all defence-related activities.

15.3.2 Department of Defence Production

The DoDP is headed by a secretary and deals with matter pertaining to defence production, indigenisation of imported stores, equipment and spares, planning and control of department production units of the ordnance factory board and defence policy sector undertaking.

15.3.3 Department of Ex-servicemen Welfare

A secretary heads this department and deals with all resettlement, welfare and matters related to pension of ex-servicemen.

15.3.4 Defence Research Development Organisation (DRDO)

The scientific adviser of Defence Ministry is the secretary and the authority, which heads the DRDO. It was established in 1958.

DRDO takes care of developing defence technologies, which covers different fields such as aeronautics, armaments, electronics, land combat engineering, life sciences, materials, missiles, agriculture, communication systems and naval systems, etc. **55 per cent of our defence system needs are fulfilled by DRDO.** The vision of DRDO is to make India prosperous through world-class establishments of science and technology. DRDO also provides our defence services, a decisive edge by equipping them with internationally competitive systems and solution.

In 1980, a separate Department of Defence Research and Development was formed. Later on, it was involved in administering DRDO and its 52 laboratories/ establishments. The first major project started by DRDO was in SAM (Surface-to-Air Missile) known as **Project Indigo** in 1960s. In later years, Indigo got discontinued without achieving the complete success. It led to **Project Devil,** along with **Project Valiant,** for development of short-range surface-to-air missile and ICBM in the year 1970. Under IGMDP in the year 1983, Project Devil led to the later development of the Prithvi missile. An Indian Ministry of Defence programme between the early 1980s and 2007 was named **IGMDP (Integrated Guided Missile Development Programme).** It was launched to develop a comprehensive range of missiles, which includes the Agni missile, Prithvi ballistic missile, Akash missile, Trishul missile and Nag Missile.

DRDO is responsible for the development of technology for use by the Indian armed forces. Despite this, DRDO has been criticised for the delayed projects and over-budgeted costs. Apart from the criticism, DRDO is engaged in two programmes: (1) Missile Programme and (2) Weapons Programme.

15.3.5 Defence Acquisition Council (DAC)

In order to tackle corruption and accelerate decision-building in military procurement, the Union government, in the year 2001, decided to form a comprehensive DAC, being headed by the Defence Minister. Its objective is ensuring **speedy procurement of the approved requirements of the Armed Forces,** in respect of sought capabilities and prescribed time frame, through effective utilisation of the allocated budgetary resources. The **DAC is responsible for providing policy guidelines** to acquisitions, on the basis of long-term procurement plans. It also clears all acquisitions, inclusive of both imported and indigenously manufactured or under a foreign licence.

DAC accorded approval for equipment procurement worth ₹9,100 crores. *DAC has approved Akasli Missile systems and IUWBA procurement:*

BALLISTIC VERSUS CRUISE MISSILE

- Ballistic Missiles always follow parabolic path but Cruise Missiles are horizontal to the surface. Ballistic Missiles change their own atmosphere but Cruise Missiles are always in same atmosphere.
- Ballistic Missiles can vary widely in terms of range and use. Hence, their division can often be based on range. Different countries use different schemes for categorising the ranges of Ballistic Missiles:
  1. **Tactical Ballistic Missile:** Its range is between 150 and 300 kilometres.
  2. **Theatre Ballistic Missile (TBM):** Its range is between 300 and 3,500 kilometres.
  3. **Short-Range Ballistic Missile (SRBM):** Its range is between 300 and 1,000 kilometres.
  4. **Medium-Range Ballistic Missile (MRBM):** Its range is between 1,000 and 3,500 kilometres.
  5. **Intermediate-Range Ballistic Missile (IRBM)** or **Long-range ballistic missile (LRBM):** Its range is between 3,500 and 5,500 kilometres.
  6. **Intercontinental Ballistic Missile (ICBM):** Its range is greater than 5,500 kilometres

Intercontinental Ballistic Missiles or ICBMs:

- Intercontinental Ballistic Missiles or ICBMs are guided missiles which can deliver nuclear and other payloads. ICBMs have a minimum range of 5,500 km, with maximum ranges, varying from 7,000 to 16,000 km.
- Only a handful of countries, including **Russia, United States, China, France, India and North Korea,** have ICBM capabilities.

Akash Missile Systems: The Missile to be acquired is an advanced version of the earlier inducted Akash missiles and will **be inclusive of seeker technology, having 360 degree coverage** and of compacted configuration with abridged signature. **The advanced Akash Weapon System is operationally crucial equipment, thereby, proving protection to essential assets.**

The DAC also accorded approval for moving ahead regarding ***Individual Under Water Breathing Apparatus (IUWBA)*** design and development **for T**

90 Tanks. Manufactured by DEBEL, DRDO Lab, it is used as a safety gear by the tanks crew and is needed for emergency get away while negotiating water impediments during deep fording.

15.4 INTEGRATED GUIDED MISSILE DEVELOPMENT PROGRAMME (IGMDP)

In 1983, the Government of India launched the Integrated Guided Missile Development Programme to achieve self-sufficiency in the development and production of wide range of Ballistic Missiles. The IGMDP, as an Indian Ministry of Defence programme between the early 1980s and 2007, worked to develop a comprehensive range of missiles, which includes the **intermediate-to-long-range Agni Missile (Surface-to-Surface) and short-range missiles like the Prithvi Ballistic Missile (Surface-to-Surface), Akash Missile (Surface-to-Air), Trishul Missile (Surface-to-Air) and Nag Missile (Anti-Tank).** The DRDO manages the programme in partnership with other Indian government labs and research centres. The programme has met with significant success in the form of Agni Missiles and the Prithvi Missiles – the two most important of its constituents. On the other hand, significant orders have been seen by two other programmes – the Akash SAM and the anti-tank Nag Missile. A programme aimed to develop a tri-service short-range SAM, namely the Trishul Missile, faced persistent problems throughout its development, and hence, was shut down in 2007.

DR. A.P.J. KALAM IS THE MISSILE MAN OF INDIA

- In 1965, he started to work on an expandable rocket project independently at DRDO. Later on, Kalam single-handedly got the government to expand his independent programme and include more engineers. There came Kalam's first stint with aerospace engineering in 1969.
- He became the Project Director for India's first Satellite Launch Vehicle (SLV-III) at Indian Space Research Organisation (ISRO), which launched the Rohini Satellite in 1980.
- Kalam worked on developing the Polar Satellite Launching Vehicle (PSLV) and SLV-III projects between the years 1970 and 1990. Both projects were met with success.
- The two secret missile programmes, which primarily earned Kalam the alias 'the Missile Man of India', were Project Devil and Project Valiant. Both projects were top secret liquid-fuelled missile projects, indigenously developed under the directorship of Kalam and with special permission by Prime Minister Indira Gandhi. Later on, these projects served as the foundation in the development of Ballistic Missile Prithvi. Then came the ₹388 crore project, known as Integrated Guided Missile Development Programme (IGMDP), headed by Kalam as the chief executive. This was the project where Kalam played a monumental role in developing supersonic missiles Agni (an intermediate range Ballistic Missile) and Prithvi.
- Kalam played an intensive political and technological role, being the Chief Scientific Advisor to the PM and Secretary of Defence, during the Pokhran-2 nuclear tests that were conducted between 1992 and 1999.

On **May 07, 2008,** the closing of the Strategic Integrated Guided Missile Programme was announced by India. It was also mentioned that the development and production would, henceforth, be taken up with foreign partnerships, for most of the futuristic weapons systems.

15.4.1 Prithvi

Under the IGMDP programme, the first missile to be developed was Prithvi. It was inducted into the Indian Army in 1994. Prithvi Missiles have three variants (**Table 15.1**).

TABLE 15.1 Different Variants of Prithvi Missile

Missile	Version	Distance	Warhead
Prithvi-I	Army	150 km	1000 kg
Prithvi-II	Air force	250 km	500–1000 kg
Prithvi-III	Navy	350 km	1000 kg

Note:

PRAHAR

- Prithvi I Missile will be replaced by Prahar Missile soon.
- PRAHAR – Prahar is a solid-fuelled surface-to-surface guided short-range Ballistic Missile indigenously developed by DRDO. It could be used for hitting both strategic and tactical targets, being equipped with omni-directional warheads, and has a range of about 150 kilometres. It was test-fired successfully on 21 July, 2011 from the Integrated Test Range (ITR) at Chandipur. Prahar is to replace Prithvi I Missile soon.
- 'Prahar', manufactured by the DRDO, has the capability of bridging the gap between the multi-barrel rocket system 'Pinaka' and medium-range ballistic missile 'Prithvi'. It can also undertake numerous targets in different directions.
- It has 7.3 metre length, it's 420 mm in diameter and it weighs nearly 1,280 kg. It is 150 km in range and 35 km in flight altitude.
- It is a solid-fuelled short-range missile integrated with inertial navigation system.

- The missile is outfitted with modern navigation, guidance and electromechanical actuation systems along with aboard sophisticated computer.
- It is a responsive, all-weather, all-terrain and extremely precise battleground support strategic weapon system.

Pradyumna Ballistic Missile

- The Pradyumna Ballistic Missile is the name of Prithvi Air Defence Missile, developed to use as an anti-Ballistic Missile system.

Dhanush

- It is a variant of surface-to-surface or ship-to-ship Prithvi III Missile, Dhanush which has been developed for the Indian Navy. It is capable of carrying both types of warheads like conventional as well as nuclear with payload capacity of 500–1000 kg and can strike targets in the range of 350 km. This missile got various test-fired successfully. Depending on the range, the Dhanush Missile can be used for destroying land targets and as an anti-ship weapon as well.

Prithvi II

- A successful training launch of a Short-Range Ballistic Missile, Prithvi-II was carried out on January 10, 2023 from the Integrated Test Range, Chandipur off the coast of Odisha.

15.4.2 Trishul Missile System

It is a short-range surface-to-air missile with a range of 9–12 km and fitted with a 5.5/15/130 kg warhead. The Trishul Missile project was officially shut down on 27 February, 2008.

Note: **Maitri Missile:** Due to the failure of Trishul missile, Maitri Missile will be launched. It is believed to be a blend of French Mica and DRDO Trishul. This missile has low-level quick reaction time. It was in news (in 2017), Maitri missile would not be developed because Barak Missile will take that place.

4.3 Nag Missile System

Nag is an indigenously built third-generation 'Fire-and-Forget' anti-tank missile. The three different types of guidance that have been available with Nag include a wire-guided version, an infrared version and a millimetric wave version.

Note: **Fire and Forget:** It means the Missile guidance does not require further guidance after the launch and still hits the target without the launcher being in line-of-sight of the target.

The missile has a weight of 42 kg and ranges between 4 and 5 km. With the claim of being the first anti-tank missile with complete fibreglass structure, this missile marked a significant evolution in development of the missile system of India. A tracked vehicle known as **NAMICA (Nag Missile Carrier)** was deployed to test the land version of this missile. Its configuration is to enable its use on the Advanced Light Helicopter (ALH) and the Hindustan Aeronautics Limited (HAL) Light Combat Helicopter (LCH). This version will be called as **HELINA (HELIcopter based NAg).** Nag was successfully test-fired from the test range at Pokhran, Rajasthan, for the second day in a row on 8 August, 2008. This marks the completion of its developmental tests.

MAN PORTABLE ANTI-TANK GUIDED MISSILE (MPATGM)

In a major boosting of Army, DRDO has effectively test-fired indigenously produced, low weight, fire and forget Man Portable Anti-Tank Guided Missile (MPATGM).
About MPATGM:

- It is third-generation Anti-Tank Guided Missile (ATGM), indigenously manufactured by DRDO.
- It has striking range of 2.5 km and weighs approximately 15.5 kg for maintaining man portability. It is also proficient of being fired from shoulder and can be fired during day and night. It has least lateral centre and gravity offset.
- It works on the principle of fire and forget. It is known for its capabilities of top attack. It is useful against together stationary and moving targets and will be positioned in the Indian Army's infantry and parachute battalions.

The Agni Missile represents a family of medium to intercontinental range of indigenously developed Ballistic Missiles. Being surface-to-surface Ballistic Missile, Agni Missiles are nuclear weapons capable. Under the Integrated Guided Missile Development Programme, the first missile of the series Agni-I was developed, and tested in 1989. Comparison of different variants of Agni missiles are mentioned in **Table 15.2.**

TABLE 15.2 Different Variants of Agni Missile

Missile	Warhead (kg)	Range (km)	Fuel Stages (Propellant)
Agni – I	1000	700–1200 (Short Range to Medium Range)	Single – solid
Agni – II	750–1000	2000–2500 (Medium Range to Intermediate Range)	Two – solid, solid
Agni – III	1500	2500–3500 (Intermediate Range)	Two – solid, solid
Agni – IV	800–1000	3000–4000 (Intermediate Range)	Two – solid, solid
Agni – V	1500	5000–8000 (Intercontinental Range)	Three – solid, solid, solid
Agni – VI	1000	6000–12000 (Intercontinental Range)	Three – solid, solid, solid

15.4.4 Agni Missile

Agni-I It is capable to cover the range of 700–1200 km and, at the same time, capable of carrying a conventional warhead of 1000 kg or nuclear warhead at a **speed of 2.5 km per second.** It consists of one stage in the short range and two stages in the intermediate range.

Agni-II It is capable to cover the range of 2000–2500 km and can carry the conventional or nuclear warhead up to 1000 kg at a **speed of 3.9 km per second or Mach 12.** It is built upon solid propellant in both stages.

Agni-III It has capability to cover the range of 2500–3500 km and can have a warhead of 1.5 tonnes, at the **speed of Mach 13.** It is built upon the powerful solid propellant in its both stages.

Agni-IV Earlier it was known as Agni-II Prime. It has capability to cover the range of 3000–4000 km and capable to carry a warhead weighing more than 800 kg. It has two stages, powered by solid propellant.

Agni-V It is a solid-propelled Intercontinental Ballistic Missile (ICBM) and it will cover a range of up to 5000–8000 km. It has been designed with third composite stages and a semi-cryogenic engine has been used in the third stage (not officially declared). It can carry a warhead approximately weighing 1500 kg at a **speed of Mach 24.**

Note: New Generation Ballistic Missile 'Agni Prime' was successfully flight-tested by Defence Research and Development Organisation (DRDO) from Dr APJ Abdul Kalam Island off the coast of Odisha on June 07, 2023.

15.4.5 Akash Missile System

Akash is a medium range, surface-to-air missile. It marks to be the most expensive missile project ever undertaken by the Government of India in the 20th century. Its interception range is 30 km. **Its launch weight is 720 kg.** Akash moves with supersonic speed and reaches around **Mach 2.5.** The altitude which it can reach is 18 kilometres.

Akash Missiles have **integrated ramjet propulsion system.** The missile is supported by a multi-function and multi-target phased array fire control radar, which is known as the **'Rajendra'.**

15.5 QUICK REACTION SURFACE-TO-AIR MISSILES (QRSAM)

India has effectively test-fired two indigenously developed ***Quick Reaction Surface-to-Air Missiles (QRSAM)*** from a test range off the Odisha coast.

- It has been developed to replace the 'Akash' missile defence system and has 360-degree coverage.
- It uses solid fuel propellant and has a range of 25–30 km with the ability to strike multiple targets.
- It has the ability of striking the low flying objects.

15.6 SHAURYA MISSILE SYSTEM

Shaurya is a **short-range, surface-to-surface, hypersonic, Ballistic Missile** to be used by the Indian Army. It has a range of 600 km and can carry a warhead, weighing up to one-tonne (conventional or nuclear). It represents a land version of the under-water launched K-15 Missile, Sagarika (Missile). It can reach to an altitude of 40 km and distance of this missile is 800 km with a speed of 7.5 times than speed of sound.

15.7 ANTI-BALLISTIC MISSILE SYSTEM

The Indian Ballistic Missile Defence Programme is a significant initiative to develop and deploy a multi-layered Ballistic Missile defence system to enable protection from Ballistic Missile attacks.

It consists of two interceptor missiles, including the **Prithvi Air Defence (PAD) missile for high-altitude interception** and the **Advanced Air Defence (AAD) missile for lower-altitude interception.** The two-tiered shield makes it capable of intercepting any incoming missile launched 5,000 km away.

In November 2006, the PAD was tested, which was followed by the AAD in December 2007. Thus, India emerged as the fourth country to have successfully developed an Anti-Ballistic Missile system, following United States, Russia and Israel, after the test of PAD.

15.7.1 Prithvi Air Defence (PAD)/Pradyumna Ballistic Missile Interceptor

For intercepting incoming Ballistic Missiles outside the atmosphere (exo-atmospheric), the Prithvi Air Defence (PAD), which is an Anti-Ballistic Missile, was developed. The PAD is a two-stage missile, based on the Prithvi Missile, and has a maximum interception altitude of 80 km. Solid-fuelled motor comprises the first stage, whereas the second stage is liquid-fuelled. PAD can engage the 300–2,000 km class of Ballistic Missiles at a speed of Mach 5. Being active-phased array radar and having the capability to track 200 targets at a range of 600 km, the PAD Missile is also called 'Pradyumna'. The interception range was further improved from 50 to 80 km. Like the technology used by Israel, the US and Russia, a gimballed directional warhead will be utilised by the improved missile. A smaller warhead is enabled through this technology to destroy the target missile.

15.7.2 Advanced Air Defence (AAD)/Ashwin Ballistic Missile Interceptor

Advanced Air Defence (AAD), an Anti-Ballistic Missile, is designed for intercepting incoming Ballistic Missiles in the endo-atmosphere at an altitude of 30 km. AAD is a single-stage, solid-fuelled missile. The guidance is like that of PAD – it has an equipped inertial navigation system, midcourse updates from ground-based radar and active radar homing in the terminal phase.

3 India Joins US, Russia, China Hypersonic Missile Club

Recently, India successfully flight tested the indigenously developed Hypersonic Test Demonstrator Vehicle (HSTDV) and became the fourth country after the United States, Russia and China to develop and successfully test hypersonic technology.

Significance and implications of this test flight:

- This indigenously developed technology paves to develop hypersonic weapons that can travel six times faster than the speed of sound (Mach 6).
- The HSTDV is an **unmanned scramjet demonstration aircraft for hypersonic speed flight.**
- The HSTDV cruise vehicle is mounted on a solid rocket motor, which will take it to a required altitude, and once it attains certain much numbers for speed, the cruise vehicle will be ejected out of the launch vehicle. Subsequently, the scramjet engine will be ignited automatically.

Way ahead

It has utility for long-range cruise missiles of the future and it can be also used for launching satellites at low cost too.

15.8 CRUISE MISSILES

15.8.1 Nirbhay

Nirbhay is an all-weather, long-range Cruise Missile. It can carry conventional and nuclear warheads with subsonic speed (0.8 mach). With a range of more than 1000 km, its weight is about 1500 kg. A solid rocket booster enhances the missile for take-off, developed by Advanced Systems Laboratory (ASL). Missile will be for use by all the three defence services, the Indian Army, Indian Navy and the Indian Air Force. It can be launched from multiple platforms on land, sea and air.

15.8.2 M-54 Klub

It is a Russian multi-role missile system with a range of 250–300 km and an average speed of 0.8 Mach with a maximum of 2.9 Mach.

15.8.3 Popeye

India procured this missile from Israel. Popeye can carry nuclear warheads, has a range of 80 km and can be launched from planes.

15.8.4 Ametist

India procured this missile from the Soviet Union. It was a land-based Cruise Missile in place of submarine launched. It can carry nuclear warheads up to the range of 50–65 km.

15.8.5 Moskit

India procured this missile from Russia. This missile is a supersonic ramjet, which can be launched from ships and lands with a range of 120 km.

15.8.6 BrahMos

An agreement was signed by India with Russia to design, develop, manufacture and market a Supersonic Cruise Missile System in 1998. By 2006, it has been successfully accomplished. It was the world's fastest Cruise Missile with speeds of Mach 2.5 to 2.8 (supersonic speed), first developed in India. In that time, in terms of speed, it was about three and a half times faster compared to the American subsonic Harpoon Cruise Missile.

It can be launched from submarines, ships, aircrafts or land. It was a joint venture between India's DRDO and Russia's NPO Mashinostroeyenia. They have together established BrahMos Aerospace Private Limited. The acronym BrahMos is perceived from the two rivers – the Brahmaputra of India and the Moskva of Russia – which represents the confluence of the two nations. This land-based and ship-launched missile can carry a 200-kg warhead. On the other hand, the aircraft-launched variant (BrahMos A) is with a capacity to carry a 300-kg warhead.

Brahmos has a two-stage propulsion system: it has a solid-propellant rocket and a liquid-fuelled ramjet enabling sustained supersonic cruise.

India has a plan to test BrahMos II soon, as a hypersonic Cruise Missile. The laboratory testing of the missile has started. As India became a member of the MTCR in 2016, India and Russia are now looking forward to jointly develop a new generation of BrahMos Missiles with 600 km+ range and the capability of hitting protected targets with pin-point accuracy.

15.9 ASTRA BVR AIR TO AIR MISSILE

It is the indigenous Beyond Visual Range (BVR) air-to-air developed missile. It is an **all-weather; high-tech missile manufactured by DRDO and can engage and demolish enemy aircraft at supersonic speed (1.2 Mach to 1.4 Mach).** The **3.8 metres tall Astra is a radar homing missile** and the **DRDO-developed smallest missile and can be launched from different altitudes. It has a target range of 110 km when launched from a 15 km altitude, 44 km when launched from an 8 km altitude and 21 km when fired from sea level.**

15.10 MEDIUM-RANGE SURFACE-TO-AIR MISSILE

The Indian Army and DRDO have signed an MoU with the development of the advanced Medium-Range Surface-to-Air Missiles (MRSAM). It is an all-weather, mobile, land-based air defence system and capable of multiple aerial targets, with range of more than 50 km.

In this project, Israel will help India, with the involvement of private sectors. This system will have majority of indigenous content, to boost up the Make-in-India initiative. MRSAM is a land-based variant of the Long-Range Surface-to-Air Missile (LRSAM) or Barak-8 Naval Air Defence System, which is designed to operate from naval vessels and has a range of up to 100 km.

Note: Barak-8 was also jointly developed with Israel.

15.11 MISSION SHAKTI: FIRST ANTI-SATELLITE MISSILE SYSTEM OF INDIA

India successfully carried out its first **anti-satellite (ASAT)** missile test in space while destroying a low earth orbit satellite through the usage of a missile which covered a **300 km** distance for engaging the target.

The test places India in a selected group alongside the **US, Russia and China** – countries with demonstrated anti-satellite capability.

This test does not violate any international law or treaty obligation and is much less harmful than the Chinese ASAT test in 2007 that led to a large-scale scattering of debris in space that threatened other satellites. 'The test was done in the lower atmosphere to ensure that there is no space debris'.

This missile system was under development since 2016, after the government gave a go-ahead and is a demonstration that the Ballistic Missile Defence Programme is progressing at a good pace. DRDO said that the test, called 'Mission Shakti', was carried out from the APJ Abdul Kalam Island in Odisha and the interceptor was a three-stage missile with two solid rocket boosters.

15.12 SUDARSHAN (LASER-GUIDED BOMB)

In order to occupy the niche of a precision delivery mechanism, India's first laser-guided bomb, Sudarshan was developed. It is the latest weapon system and can fit to a 1000-pound gravity bomb. It uses lasers to guide it to the target with a CEP (Circular Error Probability) of 10 metres.

15.13 NASAMS-II (NATIONAL ADVANCED SURFACE-TO-AIR MISSILE SYSTEM-II)

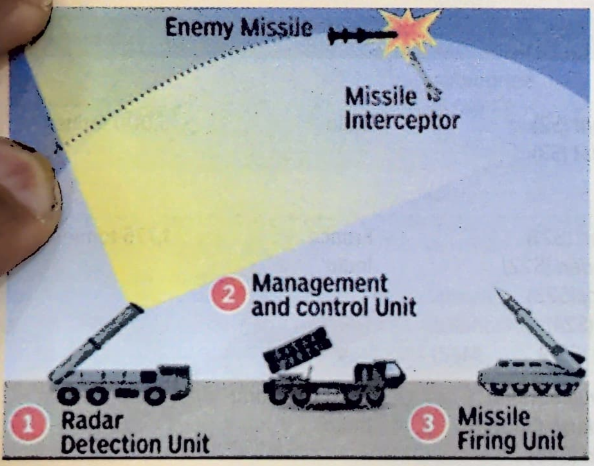
India is in negotiation with **United States** for procuring National Advanced Surface-to-Air Missile System-II (NASAMS-II), a **superior air defence system** at the outlay of **$1 billion** for **shielding National Capital Region (NCR) from airborne attacks.**

NASAMS-II is an upgraded version of the NA-SAMS, developed by Raytheon (US defence contractor and company), in association with Norway KONGSBERG Defence and Aerospace and is operational since 2007.

It is equipped with radars of latest 3D mobile surveillance and 12 missile launchers for immediate reaction. **NASAMS-II is extremely adjustable mid-range answer for any requirement of working air defence.** It offers modern defence system which **maximises the capability for rapidly identifying, engaging and destroying recent and evolving enemy aircraft, UAV or emerging threats of Cruise Missile.**

NASAMS-II is **equipped with 3D Sentinel radars, launchers, short and medium-range missiles, centres of distribution and command-and-control units for rapidly detecting, tracking and shooting down multiple airborne threats.** It is a division of the air defence network, safeguarding Washington DC, US capital city and also positioning in numerous NATO countries.

NATIONAL ADVANCED SURFACE-TO-AIR MISSILE SYSTEM-II



- Armed with 3-D Sentinel radar, short- and medium-range missiles, launchers, fire-distribution centres.
- Quickly detects, tracks and shoots down multiple airborne threats such as Cruise Missiles, aircraft and drones.
- Deployed to guard US and several NATO countries, Israel, Russia and European militaries also deploy them.
- India's own shield is in the final stages of development by DRDO. It will be deployed to protect cities like Delhi and Mumbai.

India's acquisition of NASAMS-II **will assist in prevention of 9/11-type on NCT Delhi.** It will also enhance the country's other systems under procurement such as the medium and long-range Surface-to-Air Missile (SAM) method. **By this, India will join nations league consisting of the US, Russia and Israel, etc., which possess their own missile defence systems for protecting their respective national capital regions.**

15.14 NUCLEAR TEST OF INDIA

India's first nuclear test was held on 18 May 1974. Since then, another series of tests have been conducted by India in 1998. India has extensive civil as well as military nuclear programmes. Besides that, India has heavy water production facilities, a uranium-enrichment plant, fuel-fabrication facilities, as well as extensive nuclear-research capabilities. In 1998, temporary economic sanctions were imposed by the United States and Japan on India in response to the continuing tests conducted by India.

15.14.1 Command and Control of Atom Bomb

In terms of civil leadership, the CCS (Cabinet Committee on Security) is the only authorised body, which can order a nuclear strike against another offending strike. In effect, the Prime Minister is the real authorising body who has his finger 'on the button'.

TABLE 15.3 Nuclear Programme of India

Nuclear programme start date	1967
First nuclear weapon test	18 May 1974 (Smiling Buddha)
First fusion weapon test	11 May 1998 (disputed)
Last nuclear test	13 May 1998
Total tests	6
Maximum missile range	3,500 km (Agni-III)

15.15 POPULAR BOMBS

There are two types of bombs used worldwide: conventional warheads and nuclear warheads. Some bombs that are very popular worldwide are given below:

15.15.1 Atomic Bombs

Atomic bomb is a fission bomb. It develops its energy from the fission of heavy, unstable nuclei (radioactive element) like uranium and plutonium, which are especially susceptible for fission. This is described in Nuclear Energy chapter. Little Boy and Fat Man were the names of the two atom bombs dropped on Hiroshima and Nagasaki by America-based superfast bomber plane B-29 (of these two bombs, one is uranium and the other is plutonium-based).

15.15.2 Hydrogen Bombs

Hydrogen bomb works on the principle of nuclear fusion of hydrogen isotopes. It is highly explosive in comparison to an atom bomb. Fission is required before fusion reaction because higher temperature, in the order of millions of degrees centigrade, is required for the fusion of two hydrogen isotopes. Hydrogen bomb is easy to use in missiles due to its small size.

15.15.3 Thermobaric Bomb

US in 2017 dropped a **G-43 Massive Ordnance Air Blast (MOAB) bomb,** which is popularly known as **'Mother of all bombs',** on Afghanistan. It utilises oxygen from the surrounding air to generate an intense high-temperature blast wave that generates incredible amount of energy into a small, localised area. GBU-43 has **8,000 kg of explosives.** Russia also possesses a thermobaric bomb that is popularly known as 'Father of all bombs', which is four times more powerful than the US weapon.

15.16 NUCLEAR SUBMARINES

These are submarines powered by a nuclear reactor. They are considerably advantageous, in terms of their performance over 'conventional' (typically diesel-electric) submarines. The nuclear reactor generates enormous amount of power, which enables nuclear submarines to operate at high speed for a longer span of time. Current generations of nuclear submarines need not to be refuelled throughout their life spans of 25 years. List of commissioned, under construction and decommissioned submarines are mentioned in (Table 15.4, Table 15.5 and Table 15.6).

TABLE 15.4 In Service

Class	Type	Boats	Origin	Displacement
Nuclear-powered submarines (2)				
Arihant class	Ballistic missile submarine (SSBN)	INS *Arihant* (S2) INS *Arighat* (S3)	India	6,000 tonnes
Diesel-electric submarines (16)				
Kalvari class (Scorpène-class)	Attack submarine	INS *Kalvari* (S21) INS *Khanderi* (S22) INS *Karanj* (S23) INS *Vela* (S24) INS *Vagir* (S25)	France India	1,775 tonnes
Shishumar class (Type 209 submarine)	Attack submarine	INS *Shishumar* (S44) INS *Shankush* (S45) INS *Shalki* (S46) INS *Shankul* (S47)	West Germany India	1,850 tonnes
Sindhughosh class (Kilo-class)	Attack submarine	INS *Sindhughosh* (S55) INS *Sindhuraj* (S57) INS *Sindhuratna* (S59) INS *Sindhukesari* (S60) INS *Sindhukirti* (S61) INS *Sindhuvijay* (S62) INS *Sindhurashtra* (S65)	Soviet Union Russia	3,076 tonnes

TABLE 15.5 **Under Construction**

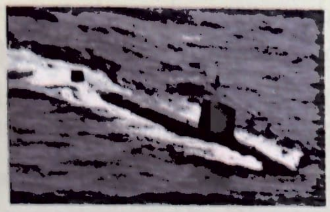
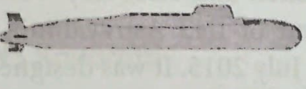
Class	Picture	Type	Boats	Origin	Displacement	Status
Nuclear submarines (2)						
Arihant class		Ballistic missile submarine (SSBN)	S4 (code name) S4* (code name)	India	7,000 tonnes (S4 and S4*)	S4 launched and undergoing fit-out S4* hull under construction
Diesel-electric submarines (1)						
Kalvari class		Attack submarine	INS Vagsheer (S26)	France India	1,870 tonnes	INS *Vagsheer* launched on 20th April 2022; Harbor trials expected to commence soon, followed by sea trials

TABLE 15.6 **Planned**

Class	Picture	Type	Boats	Origin	Displacement	Status	Note
Nuclear submarines (10)							
S5 class		Ballistic missile submarine (SSBN)	3	🇮🇳 India	13,500 tonnes	3 planned	Project was approved with a budget of ₹10,000 crore (US$1.3 billion).
Project 75 Alpha		Attack submarine (SSN)	6	🇮🇳 India	6,000 tonnes	6 planned	6 boats are planned and are expected to be constructed at the Shipbuilding Centre (SBC) at Visakhapatnam. Project clearance was granted by the Cabinet Committee on Security in February 2015.
Akula class		Attack submarine (SSN)	0	🇷🇺 Russia	12,770 tonnes	1 planned	In March 2019, India signed a US$3 billion agreement with Russia to lease another Akula-class submarine, which is expected to join the Indian Navy by 2025.
Diesel-electric submarines (6)							
Project 75I-class submarine		Attack submarine (SSN); possibly Cruise missile submarine (SSG)	6	🇮🇳 India	Unspecified	6 planned	It had been approved by the government worth ₹43000 crore in June 2020. However due to unrealistic requirements in the RFI, vendors have pulled out of the project as of 2022. It is likely to be scrapped and alternative ways of procurement looked at.

Source: DRDO, (GOI) Sites

15.17 FRIGATES, DESTROYERS AND AIRCRAFT CARRIERS

Besides the submarines, ships like destroyers, modified patrol crafts and frigates are also maintained by India. These are capable to launch nuclear-capable Ballistic and Cruise Missiles.

15.17.1 Destroyer

The largest type of surface combatant that is currently available is destroyer. They have steadily grown in size (now 5,000 to 10,000 tonnes) and capability. A destroyer, generally, is considered to be a ship with all of the sensors (which includes sophisticated phased array radars), combat systems and weapons required to operate in a high-threat environment. Many of the world navies are currently involved in building ships that, while called frigates, more accurately affirm destroyers in size and capability.

15.17.2 Frigates

A frigate, a medium-sized surface combat (between 2000 and 5000 tonnes) is either suited for a specific role (anti-submarine warfare or anti-air warfare) or has lesser all-round capabilities compared to a destroyer. However, it is still a relatively sophisticated platform, which is expensive. A frigate is generally the smallest surface combatant that can conduct the extended blue-water missions in environment that involves high-threat.

15.17.3 Aircraft Carrier

An aircraft carrier is a warship, serving as a sea-going airbase, equipped with a full-length flight deck. It also facilitates carrying, arming, deploying and recovering the aircraft. They are expensive to build and, hence, are critical assets.

'INS Vikramaditya', 45,400 tonnes, is a modified Kiev-class aircraft carrier. On 20 January 2004, after an extensive upgrade at Sevmash Enterprise, Russia agreed to sell Admiral Gorshkov to India. On 16 November 2013, the carrier, now christened INS Vikramaditya got commissioned into the Indian Navy. In 2017, INS Viraat, which was previously called as the Royal Navy's HMS Hermes, retired from the active service. Hence, India, at present, has only one aircraft carrier.

India initiated the construction of a 40,000-tonnes and 260-metre-long Vikrant-class aircraft carrier in 2009. Along with the Indian-made helicopter Dhruv, the new carrier will operate MiG-29K and naval Tejas aircraft. A second Vikrant-class carrier, namely, INS Vishal with a displacement of over 65,000 tonnes is planned and it is quite likely to be nuclear-powered with CATOBAR system for launching and recovering heavier aircraft and unmanned combat aircraft. As of April 2015, the project was in design phase (originally planned to be induced by 2020s; however, as per recent update, it may not be expected to enter into service until the 2030s).

15.18 RECENT INS IN NEWS

15.18.1 INS Astradharni

It is the first indigenously built warship by Indian Navy. It is a Torpedo Launch and Recovery Vessel (TLRV) and is a replacement of INS Astravahini, which was decommissioned in July 2015. It was designed by Naval Science and Technological Laboratory (NSTL), IIT Kharagpur and Shoft shipyard. It can easily carry two officers, 27 sailors and 13 scientists.

15.18.2 INS Karanj (Scorpene-Class Submarine)

INS Karanj is the third of the six Scorpene-class submarines under the Project 75 programme of Indian Navy. The first one, INS Kalavari (named after the tiger shark) was commissioned on December 2017. The second one, INS Khandari is undergoing the sea trials. The remaining three submarines, Vela, Vagir and Vagsheer, are in various stage of outfitting. The Scorpene Submarines can undertake various missions such as anti-surface warfare, anti-submarine warfare, intelligence gathering, mine laying and area surveillance.

15.18.3 INS Aridhaman (Arihant-Class Submarine)

Aridhaman, the second Arihant-class nuclear-powered Ballistic Missile Submarine. It is a nuclear-powered Ballistic Missile Submarine, indigenously built under the Advanced Technology Vessel (ATV) project at Visakhapatnam and powered by a pressurised water reactor. After the induction of INS Arihant and INS Aridhaman, India became the sixth country in the world to have a nuclear-powered submarine, after the USA, the UK, China, Russia and France.

Note: INS Arihant was an indigenous nuclear-powered submarine, which was built under the Advanced Technology Vessel Project. It is based on the design of the Russian Project 971 Akula I-class nuclear-powered attack submarine.

15.18.4 INS Kiltan (Built under Project 28)

INS Kiltan is a kamorta-class Anti-Submarine Warfare (ASW) stealth corvette, which was commissioned by the Indian Navy and being built under naval project P-28. It is India's first major warship developed with carbon-fibre composite material to have stealth features. It was designed by Directorate of Naval Design and constructed by Garden Reach Shipbuilders and Engineers Limited, Kolkata.

Note: INS Kamorta and INS Kadmatt were two ships constructed under the same project.

8.5 INS Kavaratti

- It is an Anti-Submarine Warfare (ASW) ship to be commissioned into the Indian Navy.
- It has up to 90% indigenous content.
- It is the last of four indigenously built ASW under 'Project 28' or Kamorta-class corvettes of the Navy.
- **'Project 28'** was approved in 2003. The other three warships under this project are INS Kamorta (commissioned in 2014), INS Kadmatt (2016) and INS Kiltan (2017).

15.19 FIRST INDIGENOUSLY BUILT FLOATING DOCK

The Indian Navy launched its first indigenously built Floating Dock (FDN-2) at the shipyard in Kattupalli, near Ennor Port, Chennai. This dock is 185-metres long and 40-metres wide. This will enable docking of all kinds of vessels, including naval ships and submarines of up to 8,000 tonnes displacement.

15.20 DIFFERENT GENERATION OF AIRCRAFT

First-Generation Aircrafts (mid-1940s to mid-1950s) E.g.: Messerschmitt Me 262, MiG-15 and MiG-17.

These have subsonic speeds, straight wings, lack of radar and machine guns as primary weapon and unguided bombs.

Second-Generation Aircrafts (mid-1950s to early 1960s) E.g.: MiG-21, Su-9 and F-106, F-104 star fighter, F-5, MiG-19 and Sukhoi-7, etc.

They had turbojet engines, are equipped with radars and utilise air-to-air missiles as the primary weapon. They are enabled to reach and sustain supersonic speeds in level flight by the-aerodynamic engine. Nuclear warfare environment distinguishes jet fighters into two categories: Interceptors (MiG-21, SU-9, F-106) that are specialised in preventive missions against enemy bombers and aerial reconnaissance flights, which were fighter-bombers (F-105, SU-7) providing air superiority and ground attack.

Third-Generation Aircrafts E.g.: Mirage F1, MiG-23, MiG-25, F-4 and F-5 are the third-generation aircrafts that are equipped with advanced avionics and aerodynamic performance. Moreover, they also include air guided missiles, air-to-air missiles and radar systems. However, due to poor accuracy of weapons and electronic countermeasure (device, which are designed to trick detection system), it was not easy to win an air fight.

Fourth-Generation Aircrafts E.g.: MiG-29, MiG-27, Mirage-2000, Su-27, F-16 and F-18.

Since the movements of flight controls are converted to electronic signals, transmitted by wires, they are termed as fly-by-wire. The 'fly-by-wire system' also enables automatic signals, sent by the aircraft's computers for operating functions without the pilot's input, just like systems that automatically help in stabilising the aircraft, or preventing unsafe operation of the aircraft outside its performance envelope. 'Thrust vectoring technology' was introduced to enhance a fighter's turning ability further, as introduced in Soviet fighters.

5th Generation Fighter Planes (late 1990s and into the 2005) It is equipped with Active Electronically Scanned Array (AESA) radar system. Radar absorbent materials, thrust vector controlled engines, greater weapons carriage capacity (Supercruise) are some significant features of this class. Addition of stealth technology is also possible. E.g.: Eurofighter Typhoon, Saab JAS 39 Gripen and Dassault Rafale (Medium

Multi-Role Combat Aircraft, MMRCA). This category of fighter aircrafts has a greater scope to conduct multi-role missions.

Fifth-Generation Jet Fighter This jet fighter is the most advanced jet fighter generation, as of 2015. They have all-aspect stealth technology, Low Probability of Intercept Radar (LPIR), high-performance airframes, advanced avionics features and highly integrated computer systems that can network with other elements within the battle space for situation awareness.

F-22 Raptor is the only current combat-ready fifth-generation fighter. It was introduced to service with the United States Air Force in 2005. The Lockheed Martin American F-35 Lightning II, Sukhoi PAK FA, Chengdu J-20 and Shenyang J-31 are currently undergoing various stages of testing and development.

15.21 FIGHTER PLANES OF INDIA

Some of the famous fighter aircrafts are as follows:

1. **Sukhoi Su-30 MKI:** Developed by Russia and built under licence by India's Hindustan Aeronautics Limited (HAL) for the Indian Air Force. Sukhoi Su-30 is a heavy, all-weather, long-range fighter. It is a super-manoeuvrable aircraft. It can do various manoeuvres, which are not possible from a pure aerodynamic angle. It has two engines, which help it to reach a maximum speed of Mach 2 (2100 miles per hour), its new variant is fitted with BrahMos and Nirbhay Cruise Missiles.
2. **Mirage 2000:** The Dassault Mirage 2000 is a French multi-role, single-engine, fourth-generation jet fighter. IAF has used it in Kargil war against Pakistan. It can carry and launch Nuclear Cruise Missiles. This is a supersonic standoff missile, powered by a liquid-fuel ramjet. It has a maximum range of 300 km and a maximum speed is 2338 km per hour.
3. **MiG-21:** It is a supersonic jet fighter aircraft designed by Russia. Early versions are considered second-generation jet fighters, while later versions are considered to be third-generation jet fighters. In 1964, the MiG-21 became the first supersonic fighter jet to enter service with the IAF. Top speed of MiG-21 is 2175 km per hour (Mach 2).
4. **MiG-27:** It has variable geometry ground-attack aircraft originally produced by the Mikoyan Design Bureau in the Soviet Union and later licenced to be produced in India by Hindustan Aeronautics. At present, Indian and Sri Lanka Air Forces are using MiG-27 for ground attack. Maximum speed of MiG-27 is 200 metres per second.
5. **MiG-29:** Is a two-engine jet fighter aircraft, designed by the Russia company, Mikoyan. It has been developed to counter the US fighter jets, F-15 and F-16. It is a multi-role fighter capable of performing a number of different operations and is commonly outfitted to use a range of air-to-surface armaments and precision aircrafts. The maximum and cruise speed of the aircraft are 2400 km per hour and 1500 km per hour, respectively. The ferry range is 2100 km per hour.
6. **HAL Kiran:** It is an Indian two-seat intermediate jet, built by the Hindustan Aeronautics and is used by IAF for intermediate training for pilots on the F-16. It is used by the Indian Air Force's aerobatic team, Surya Kiran and Indian Naval's aerobatic team, Sagar Pawans.
7. **Hawker Siddeley HS 748:** It is a medium-sized turboprop airliner, originally designed by British firm, Avro. It was used for civilian as well as military purposes. It has a cruise speed of 281 miles per hour and a range of 1066 miles. In 2012, IAF announced the impending replacement and phasing out of old Avro Aircrafts.
8. **C-130 J Super Hercules:** The Lockheed Martin C-130 J Super Hercules is a four-engine turboprop military transport aircraft update of C-130 Aircraft. A five C-130 J-30s is in service with IAF from January 2014. It has top speed of 593 km per hour and is manufactured by the USA firm Lockheed Corporation and Lockheed Martin.
9. **SEPECAT Jaguar:** It is an Anglo-French jet attack aircraft. It is used for close air support and nuclear strike role and IAF still uses Jaguar. It has a top speed of 1,700 km per hour and a range of 3,524 km.
10. **Tu-142:** The Tupolev Tu-142 is a maritime reconnaissance and anti-submarine warfare aircraft. It has been developed by Russia with highly sophisticated combat avionics and a large payload. The Indian Naval Air Arm had eight Tu-142 in service as bared at INS Raja-li, Tamil Nadu. The operational speed of the aircraft is around 2 Mach and the maximum speed is around 3 Mach.

11. **BAE Sea Harrier:** It is a naval short take-off and vertical landing, reconnaissance and attack aircraft, developed by the British firm Hawker Siddeley Harrier. It has a top speed of 1176 km per hour.

12. **MiG-29 K:** It is a Russian all-weather, carrier-based multi-role aircraft. It is different from MiG-29; it has an air-to-air missile, along with missiles for anti-ship and anti-radar operation. Indian Navy-Naval Air has 45 MiG-29 K/KuB aircrafts. On 29 June 2015, Naval Air Arm has 33 aircrafts in inventory. It has a top speed of 2,200 km per hour and the range is 2,000 km.

13. **Future Aircrafts:** The IAF has been undergoing a modernisation programme to replace and upgrade its ageing and outdated equipment since the late 1990s. The primary focus of current modernisation and upgradation is to replace aircrafts purchase from the Soviet Union that currently form the backbone of the Air Force.

4. **MiG-29 UPG:** India awarded Russia a 865 million USD contract in 2007 to upgrade its air superiority MiG-29 into multi-role MiG-29 UPG standard warplanes, which will now feature increased fuel capacity, latest avionics and air-to-air missile. The modernisation is part of a 900 million USD contract to upgrade the fleet of 66 fighter jets.

15. **Su-30 MKL:** Initially, it was not designed to carry strategic weapons. The IAF will receive 40 upgraded Su-30 MKLs, capable of carrying BrahMos Cruise Missiles, 2021. Upgraded variants will feature new active electronically scanned array radars, electronic warfare and ability to carry BrahMos missile.

16. **Mirage 2000-5 MK2:** Upgraded from Mirage 2000 M, the new variant will feature radar systems, a new weapons suite and missile electronic warfare system. It will be upgraded to next generation and it will enhance the operational life of the multi-role fighter by around 20 years.

17. **Sepecat Jaguar:** IAF decided to upgrade 125 jaguar from 2013 and placed an order of additional aircraft. New variant will be multi-made and will include radar, autopilot and other changes.

18. **HAL Tejas:** It is India's dream project; it will be a replacement aircraft for IAF's ageing MiG-21. It is a first indigenous light combat aircraft, developed by DRDO. It is developing in four variants: LCA for IAF, LCA trainer for IAF, LCA for Navy and LCA Navy trainer. Tejas will be IAF's additional aircraft for medium-role combat missions. It will have a top speed of 1920 km per hour and a range of 850 km. It is guided with air-to-air surface and anti-shipping weapons. On 17 January 2015, the first Tejas LCA was officially inducted into the IAF.

19. **Dassault Rafale:** It is a French, two-engine, canard delta wind, multi-role fighter aircraft, designed and built by Dassault Aviotion. It is intended to perform air supremacy, interdiction, aerial reconnaissance and nuclear strike missions. It has three variants: Rafale B, Rafale C and Rafale M. Rafale C is a single-seat land-based version; Rafale B is a twin-seat land-based version; and Rafale M is a single-seat carrier-based version. IAF has chosen to purchase 36 Rafale from France for 4.5 billion USD. Rafale was selected on the basis of performance and cost from the other contender aircrafts, namely: NATO's Eurofighter Typhoon, US aircraft F18, F16, Sweden's Gripen and Russia's MiG-35 aircraft. During the last stage, Rafale and Eurofighter were shortlisted; from which Rafale was selected, based on the following criteria. Rafale has a maximum speed of Mach 1.8 and a range of 3,700 km and is capable of fuelling in mid-air.

WHY WAS RAFALE IN NEWS?

The issue with Rafale is the per-unit cost. As per Brazilian media, Brazil is also buying 36 Rafales at the cost of 4.2 billion USD and an additional 4 billion USD for short-period maintenance with transfer of technology. So, one Rafale would roughly cost $209 million without maintenance. Brazil had doubts about the quality of the AESA radar, which enables the aircraft to switch quickly from air-to-air to ground mode in flight and about the helmet-mounted heads-up display. In Indian context, the deal was signed in 2009 for 126 Rafale at 10 billion USD and now the cost is increased to 22 billion USD, which roughly means 238 million USD per aircraft, compared to the 209 million USD per aircraft quoted for Brazil. Terminating the deal will now be disruptive and somehow, international politics are also a reason for creating such a scenario; hence, India also decreased its order from 126 Rafale to 36 Rafale.

15.22 HELICOPTERS OF INDIA

Dhruv primarily serves as a light utility helicopter for IAF. Besides, its transport and utility roles, newer Dhruvs are also capable of attacking. Chetak is a light utility helicopter, primarily deployed for training, rescue and light transport roles in the IAF. Dhruv is gradually replacing Chetak helicopter. Cheetah is the name of light utility helicopter, which is used for high-altitude operations. It is employed for both purposes, the transport and search-and-rescue missions of the IAF. The list of helicopters (**Table 15.7**) are given below:

TABLE 15.7 List of Helicopters

Helicopter	Origin	Role	Version
HAL Rudra	India	Attack helicopter	ALH-WSI
Kamov Ka-226	Russia	Utility helicopter	Ka-226T
HAL Dhruv	India	Utility helicopter	
HAL Cheetah	India	Utility helicopter	Cheetah Cheetal Lancer
HAL Chetak and Chetan	India	Utility helicopter	Chetak
Boeing Apache AH-64E	USA	Attack helicopter	
Chinook	USA	Utility helicopter	

Sources: HAL, (GOI SITE)

15.23 BIOLOGICAL WEAPONS CONVENTION (BWC)

As a supplement of the 1925 Geneva Protocol, a multilateral disarmament treaty (of indefinite duration that is open to any country) that bans the production of an entire category of weapons for establishing a new instrument against biological weapons, is in the form of BWC. This Convention completely prohibits the development, production and stockpiling of biological weapons. As per Geneva Protocol, possession or development of chemical and biological weapons is not prohibited but only the use is prohibited.

The British submitted this draft of the BWC that was opened for signature on 10 April 1972 and entered into force on 26 March 1975. As of 2018, it commits total 180 party states, as legally binding.

However, without any formal verification regime to monitor compliance, it meets limited effectiveness.

Article 1 of this BWC defines the scope of BWC's prohibition. All microbial and other biological agents or toxins and their means of transmission or delivery (except for medical and defensive purposes in small quantities) are included in it, **similar to Article II, 1 in the Chemical Weapons Convention (CWC).**

The BWC defines permitted purposes of biological activities like prophylactic, protective and other similar peaceful purposes.

The Biological Weapons Convention (BWC) has been ratified by India. In October 2002, reiterating the latter point, the then President Dr. A. P. J. Abdul Kalam asserted that 'India will not make biological weapons. It is cruel to human beings'.

15.24 CHEMICAL WEAPONS CONVENTION (CWC)

The Chemical Weapons Convention (CWC) represents a multilateral treaty to ban chemical weapons in no fixed duration. It is more comprehensive as compared to the 1925 Geneva Protocol that outlaws the use of chemical weapons; however, their possession is not outlawed. CWC negotiations started in 1980 in the UN Conference on Disarmament and were opened for signature on 13 January 1993 and it entered into force on 29 April 1997.

Chemical Weapons Convention is implemented by the Organisation for the Prohibition of Chemical Weapons (OPCW). The OPCW receives detailed declarations of chemical weapons-related activities or materials and its relevant industrial activities from state parties, which will be inspected and monitored by the convention. As of 2018, over 96 per cent of the world has declared to destroy their chemical weapons stockpiles. All nations can be party of CWC; it now has 193 states-parties as its members.

15.24.1 Prohibitions Under CWC

These are the following prohibitions under CWC:

- Development, production of chemical weapons and acquiring, stockpiling or retaining them.
- Direct or indirect transfer of chemical weapons.
- Their use for military purposes.
- Assisting, encouraging or inducing other states to follow CWC-prohibited activities.

In 1992, CWC was signed by India, denying possession of chemical weapons and the capacity or capability to manufacture chemical weapons. This made India as one of the original signatories of the CWC in 1993, and it ratified the same on 2 September 1996.

15.24.2 Organisation for the Prohibition of Chemical Weapons (OPCW)

The OPCW is a self-governing, autonomous international organisation that has a working association with the United Nations. The organisation is the **Chemical Weapons Convention (CWC)** executing body, which came into force in the year 1997.

The organisation was honoured with the **2013 Nobel Peace Prize** 'for its wide-ranging efforts in eliminating chemical weapons'.

The OPCW member states share the joint goal of avoiding usage of chemical weapons ever yet again being used in warfare, thus, strengthening the international security. To conclude this, the Convention contains **four key requirements:**

- Demolishing all present chemical weapons under globally verified organisations by the OPCW.
- Supervising chemical industry for preventing fresh weapons from re-emergence.
- Giving aid and security to state parties against chemical threats.
- Promoting worldwide collaboration for strengthening the implementation of the Convention and promoting the peaceful usage of chemistry.

15.24.3 The Convention of Chemical Weapons Prohibits

- Manufacturing, producing, obtaining, accumulating or preserving chemical weapons.
- Transferring of chemical weapons directly or indirectly.
- Usage of chemical weapons for military preparation.
- Aiding, encouraging or inducing other states to involve in CWC-prohibited activity.
- Usage of riot control agents 'as a method of warfare'.

EXTERNAL AUDITOR FOR HAGUE-BASED OPCW

- India's **Comptroller and Auditor General (CAG)** has been chosen as the external auditor by the **Prohibition of Chemical Weapons (OPCW)** for a three-year term, starting in 2021.
- The **appointment was made through an election process** at the OPCW conference recently.
- **India was also selected as the member of the executive council of the OPCW,** representing Asia group for another two-year term, during the OPCW conference.

EXECUTIVE COUNCIL

- It is the governing body of the OPCW.
- The Council consists of 41 OPCW Member States that are elected by the Conference of the States Parties and rotate every two years.
- The Council supervises the activities of the Technical Secretariat and is responsible for promoting the effective implementation of and compliance with the Convention.
- Each Member State has the right, on a rotating basis, to serve the Executive Council.

15.25 INDIAN TANKS

A tank is a large, heavily armoured fighting vehicle with tracks and a large tank gun, that is designed for front-line combat. Modern tanks are a mobile land-weapon platform, mounting a large-caliber cannon in a rotating gun target. Tanks are important for supporting infantry. Tanks used/being used by the Indian Army (**Table 15.8**) are as follows:

TABLE 15.8 List of Different Tanks

Arjun MBT	India
T-90S 'Bhishma' and T-90M	Russia and India
T-72, Ajeya Combat and Improved Ajeya	Soviet Union, Poland and India

Source: DRDO, (GOI Sites)

1. **AMX-13:** It is a French Light tank, produced from 1953 to 1985, was used by 25 nations, including India. Indian Army has used this tank during the war in 1965 with Pakistan. At that time, Pakistan's troops were using M-48 Pattons, which were far superior than AMX-13.

2. **Vijayanta:** It was the main battle tank, built in India based on a licensed design of the Vickers NK-I. It was the first indigenous tank of the Indian Army and was in service during 1965–2008. It has now been supplanted by the T-72 MI in Indian service.
3. **T-72:** It is a Soviet-designed main battle tank. It has two variants: T-72 N and T-72 MI. Its indigenous name is Ajeya Tank and has been used by the Indian Army from late 1990s to early 2000s.
4. **T-90:** Its indigenous name is Bhishma. In 2001, around 310 T-90S tanks were imported from Russia. It had features almost similar to T-72, with some improvements. Indian scientists are currently producing a customised and improved version of T-90 – the T-90 M Bhishma. As of now, a grand total of 500 T-90 and T-90 M tanks are being operated by the Indian Army.
5. **Tank Ex or NBT Ex:** It is India's ambitious defence project to build a battle tank after the MBT Arjun. DRDO is working on this since 2002. It will be an improved version of T-90 MI and its name would be **'Karna'**. It can withstand a nuclear, biological and chemical (NBC) attack and would be more superior and much lighter than the Arjun NBT.

MUNTRA (INDIA'S FIRST UNMANNED TANK)

It is the first unmanned, remotely piloted tank of India that has been developed by the DRDO for various surveillance missions, mine detection and reconnaissance in the areas with nuclear and biological threats. It can be used in Naxal-hit area as well. This is equipped with an integrated camera along with laser range-finder, which can spy on a ground target that is 15 km away. There are different types of Muntra tank for various levels of surveillance:

Muntra S: For surveillance mission,

Muntra M: For detecting mines and

Muntra N: For operation in areas where there is risk of nuclear or bio-weapons.

6. **Arjun Tank MK-2:** The Arjun is a third-generation main battle tank, developed by DRDO for the Indian Army. It is powered by a single MTU multi-fuel diesel engine and can achieve a maximum speed of 67 km per hour and a cross-country speed of 40 km per hour. Arjun MK-I entered service with the Indian Army in 2004, but failed to impress the army and improvements were required in order to make it combat-ready. The new Arjun MK-2 is the improved version, made available in 2012 and would now be replacing T-55 and T-72 M.

15.26 UNMANNED AERIAL VEHICLES (UAV)

UAV is a pilotless targeted aircraft, i.e., Remotely Piloted Vehicle (RPV), which typically falls into various functional categories (although multi-role airframe platforms have been becoming more prevalent):

- **Target and decoy:** Providing ground and aerial gunnery a target, stimulating an enemy aircraft or missile.
- **Reconnaissance:** To provide battlefield intelligence.
- **Combat:** To provide attack capability for high-risk missions.
- **Logistics:** In delivering cargo.
- **Research and development:** Advancement of UAV technologies.
- **Civil and commercial UAVs:** In the field of agriculture, aerial photography and data collection.
- There are many unmanned aerial vehicles, developed by DRDO, namely, Nishant, Lakshya, Rustom, etc.
  - ***Lakshya:*** Efforts are being made to develop PTA (Pilotless Target Aircraft) further, with an improved, all-digital flight control system and a better turbojet engine.
  - ***Nishant:*** Serves as a hydraulically launched short-ranged UAV, serving the tactical battle area. Currently, the Indian Navy and the Indian Paramilitary forces are evaluating it.
  - ***Panchi:*** It is wheeled version of UAV Nishant and has been designed and developed by ADE.
  - ***Dakshya:*** It is a land-based drone used for bomb disposal developed by DRDO.

The DRDO is also moving ahead with its plans for the development of a new class of UAVs. They are commonly referred with HALE (High Altitude Long Endurance) and MALE (Medium Altitude Long Endurance) designations. The MALE UAV has been tentatively named as the Rustom. India has developed many types of drones: Abhyas, AURA, Fluffy, Imperial Eagle, Kapothaka, Lakshya, Netra, Nishant, UAV, Rustom and Ulka.

TABLE 15.9 Unmanned Aerial Vehicles

Type	Class	Role	Notes
Harpy	Israel	Attack	A small UCAV capable to home into enemy radar emissions – thereby, destroying both itself and the enemy radar. In service with the IAF.
Harop	Israel	UAV	A small UCAV capable to home into enemy radar emissions – thereby, destroying both itself and the enemy radar. In service with the IAF.
Heron	Israel		In service with the IAF and Indian Navy. 15 more were ordered in December 2013.
Searcher	Israel		It is in service with Indian Army.
Nishant	India		It is in service with Indian Army.
Lakshya	India	Aerial target	A small target drone, which is in service with the IAF and Indian Navy.

27 DRONE

The formal name of drones is Unmanned Aerial Vehicles (UAV). Essentially, a drone is a flying robot. The aircraft may be controlled remotely or can fly autonomously with the help of software-controlled flight plans in their embedded systems that work in conjunction with GPS.

The first city to have a margarita pizza delivered via a drone was Mumbai, in May 2015. As per current regulations, the use of drones commercially is still illegal in India. Drones are becoming a serious issue in India, both in terms of commercial and military purposes.

15.27.1 India's Military Drones

During the 1999 Kargil War with Pakistan, India first used military drones. Heron and Searcher drones were discreetly supplied to Indian Air Force by Israel. They proved to be quite useful in acquiring target information along the Line of Control. India has procured a number of Israeli military unmanned aircrafts since Kargil War. Currently, India's arsenal includes the Israel Aerospace Industry's Harpy and Harop, unmanned combat aerial vehicles, along with Searcher and Heron, unmanned aerial vehicles.

DRDO has also developed its own domestic UAV programme. The project is aimed at developing a domestic arsenal that can replace and augment the existing fleet of IAI vehicles (Israel Aerospace Industry). There are few completed and pending DRDO project as drone of India like Lakshya, Nishant, Aura and Rustom.

15.27.2 Civilian Drones in India

Drones have been used to assist in services ranging from disaster relief, aerial photography and security and surveillance. Many civilian drones are developed – Airpix, Garuda Robotics, Edall systems, etc.

Social Drones A start-up involved in 'designing and manufacturing user-friendly, high-performance drones that can be used easily for social and unconventional applications'. During disaster-relief operation in Uttarakhand, after severe flooding in 2013, the Social Drones were used and hence, made news. Drones were used for the areas that were deemed unsafe for conventional relief methods and also for the areas where relief efforts have been stalled, the company's drones were used to airdrop first-aid kits.

15.27.3 Multiple Uses of Civilian Drones

Advancements in fields such as automation, robotics, miniaturisation, materials science, spectral and thermal imaging and light detection and ranging have resulted in drone-enabled solutions in areas as diverse as the **agriculture, power, infrastructure and telecom sectors, as well as crowd and disaster management.** UAV activity will impact proprietary interests because common law has not clearly demarcated the commons from owned airspaces. It will also raise huge privacy concerns, considering the potential deployment of drones for massive data capture and analytics. No clear guidance exists on the liability standards for midair collisions and injury to property or persons in the event of untoward incidents.

This may seem like an imaginary scenario now, but with the rapid pace in the development of drone and its software, drone spraying and spreading is not inconceivable in the near future. Manufacturers are pushing ahead with the developments to make drone spraying and spreading a practically reality. Drones can capture images of erupting craters. The main factor is the **safe accessibility of dangerous terrain.** Researchers from the German Research Centre for Geosciences, known by the German abbreviation GFZ, **revealed**

amazingly detailed data from an active volcano using drones with visual and thermal-imaging cameras. Scientists are using drones to sample whale breath and snot.

15.27.4 Recent Updates on Drones

The **Ministry of Civil Aviation (MoCA)** has sent a note on use of drones across various sectors to different ministries in the Centre.

Where can drones be effectively utilised?

- **Ministry of Home Affairs:** For surveillance, situational analysis, crime control, VVIP security, disaster management, etc.
- **Ministry of Defence:** Drones for combat, communication in remote areas, counter-drone solutions, etc.
- **Ministry of Health and Family Welfare:** Delivery of medicines, collection of samples from remote or epidemic/pandemic-affected areas.
- **The Petroleum and Natural Gas, and Power Ministries:** For real-time surveillance of assets and transmission lines, theft prevention, visual inspection/maintenance, construction planning and management, etc.
- **Environment, Forests and Climate Change Ministry:** Anti-poaching actions, monitoring of forests and wildlife, pollution assessment, and evidence gathering.
- **Ministry of Information and Broadcasting:** For high-quality videography of events and difficult to reach places at a fraction of the cost and approvals required. This move would also facilitate low-altitude shooting without noise, and prevent dust pollution and risk of accidents.
- **Other areas:** To undertake disaster management, incidence response, inspection/maintenance works and project monitoring.

Significance

Drones offer tremendous benefits to almost every sector of the economy, including but not limited to, national defence, agriculture, law enforcement, and mapping, among others.

Drone Management in India

- The Union government had on 15 September 2021, approved **a production-linked incentive (PLI)** scheme for drones and drone components with an allocation of ` 120 crore spread over three financial years.
- The ministry had on August 25 notified the Drone Rules, 2021 that eased the regulation of drone operations in India by reducing the number of forms that need to be filled to operate them from ₹25 to ₹5 and decreasing the types of fees charged from the operator from ₹72 to ₹4.

Need for Stricter Rules and Regulations

- Recently, drones were used for the first time to drop explosive devices, triggering blasts inside the Air Force Station's technical area in Jammu.
- Over the past two years, drones have been deployed regularly by Pakistan-based outfits to smuggle arms, ammunition and drugs into Indian territory.
- According to government figures, 167 drone sightings were recorded along the border with Pakistan in 2019, and in 2020 there were 77 such sightings.
- With the rapid proliferation of drone technology and exponential growth of its global market in recent years, the possibility of a drone attack cannot be ruled out even in the safest cities in the world.
- Drones are becoming security threats particularly in conflict zones where non-state actors are active and have easy access to the technology.

Drone Rules, 2021

- As on 31 December 2021, nine **remote pilot training organisations** have been set up by entities under government or private ownership.
- As per **Drone Rules, 2021,** any person who intends to obtain the authorisation to establish **a Remote Pilot Training Organisation (RPTO)** shall submit **an application to the Director General of Civil Aviation** in Form D5 on **the Digital Sky Platform,** along with the specified fees.

New Drone Rules

- **Digital sky platform** shall be developed as a business-friendly single-window online system.
- **No flight permission required upto** 400 feet in green zones and up to 200 feet in the area between 8 and 12 km from the airport perimeter.

- **No pilot licence required for** micro drones (for non-commercial use), nano drones and for R&D organisations.
- **No restriction on drone operations by foreign-owned companies registered in India.**
- Import of drones and drone components to be regulated by DGFT.
- **No security clearance required** before any registration or licence issuance.
- **No requirement of certificate of airworthiness,** unique identification number, prior permission and remote pilot licence for R&D entities.
- **Coverage of drones under Drone Rules, 2021 increased from 300 kg to 500 kg.** This will cover drone taxis too.
- **Issuance of Certificate of Airworthiness** delegated to Quality Council of India and certification entities authorised by it.
- **Manufacturer may generate their drone's unique identification number** on the digital sky platform through the self-certification route.
- **Maximum penalty** under Drone Rules, 2021 reduced to ₹1 lakh. This shall, however, not apply to penalties in respect of violation of other laws.
- **Drone corridors** will be developed for cargo deliveries.
- **Drone promotion council** to be set up to facilitate a business-friendly regulatory regime.

Drone Categories in India

- Registration is required for all but the Nano category.
- **Nano:** Less than or equal to 250 grams
- **Micro:** From 250 grams to 2 kg
- **Small:** From 2 kg to 25 kg
- **Medium:** From 25 kg to 150 kg
- **Large:** Greater than 150 kg

Significance of Drones

- Use of drones in commercial, safety, law and order, disaster management and surveillance operations **reduce manpower requirement and costs.**
- **Drones offer low-cost, safe and quick aerial surveys** for data collection and are useful for industries such as power, mining, realty and oil and gas exploration.

15.28 RADAR (RADIO DETECTION AND RANGING)

Radar is a detection system that uses radio waves for determining the range, angle or velocity of objects. It can be used for detecting aircrafts, ships, spacecraft, weather formations, motor vehicles, guided missiles and terrain.

Current Radar Systems with The Indian Armed Forces

1. **Indian Doppler Radar (INDRA-I):** INDRA is 2D mobile surveillance radar used for low-level target detection.
2. **Indra-II PC Radar:** It is a variant of INDRA radar, which is used for ground-controlled interception of targets for the Indian Air Force.
3. **Battle Field Surveillance Radar Short Range (BFSR-SR):** It is a portable, battery-operated surveillance radar.
4. **Maritime Patrol Airborne Radar XV 2004:** It is versatile maritime surveillance airborne radar that delivers excellent performances during maritime surveillance, search-and-rescue missions. It is easily adaptable to multiple platforms while searching, detecting and tracking multiple targets at long range.
5. **3D Medium Range Surveillance Radar:** ROHINI: 3D Medium Range Surveillance Radar, that is, Rohini is the ground-based mechanically scanning S-Band pulse Doppler radar, which is used for air space surveillance. It serves in detecting and tracking air targets with reliability, even under hostile electronic warfare operational environment for the Indian Air Force.
6. **3D Surveillance Radar System:** REVATHI: The scope of the radar is medium range 3D air surveillance to intercept, 3D target tracking and indication, along with sea surface surveillance as a primary sensor.
7. **3D Tactical Control Radar (3D TCR):** It is an all-weather 3D surveillance radar, which is used for detection and identification of aerial targets. It is capable of collecting pertinent data at Target Data Receiver (TDR), 20 km away from the Radar. The operational band of the radar is S-band and can Track-While-Scan (TWS) airborne targets up to a range of 90 km for fighter aircrafts and 65 km for UAVs, subject to radar horizon.

8. **Low-Level Light-Weight 2D Radar – BHARANI:** Low-Level Light-Weight L-Band 2D Radar represents a light weight and compact sensor, which is powered by battery, enabling 2D surveillance solution to alert Army Air Defence Weapon Systems, especially in mountainous terrain, against hostile aerial targets such as UAVs, helicopters and fixed-wing aircrafts that are flying at low and medium altitudes.
9. **Low-Level Light-Weight 3D Radar – ASLESHA:** It represents a multifaceted, ground-based S-Band 3D Low-Level and Light-weight Surveillance Radar, which can be deployed in diverse terrains such as plains, mountain tops, deserts and even high-altitude regions. Aslesha is capable of detecting and tracking heterogeneous air targets, which include helicopters, fighters and UAVs at low and medium altitudes.
10. **Long-Range Solid-State Active-Phased Array RADAR-LSTAR:** The system is a Long-Range, Multifunction Solid-State Active-Phased Array Radar, developed under the Technology Demonstration Programme. It mainly serves the purposes of surveillance, detection and tracking of airborne targets.
11. **FLR: Flight Level Radar for Air Force: RAJENDRA:** RAJENDRA is a multi-function radar, which is an electronically scanned phased array radar, functions as the primary sensor at the Flight level for Akash Weapon System (an air defence system for the Armed Services). The radar is capable to assist in extensive search, tracking multiple targets and missiles. It can also command and guide own multiple functions missiles concurrently. Hence, RAJENDRA fulfils multiple functions of radar, for instance, surveillance, tracking and guidance. Being mounted on two wheeled vehicles, Flight Level Radar (FLR) as well as Flight Control Centre (FCC), it provides sensor support to all Air Defence operations.
12. **Upgrades for Weapon Locating Radar (WLR): SWATHI:** It is a coherent, electronically scanned C-Band pulse Doppler radar. The radar is capable of automatically locating hostile artillery, mortars and rocket launchers and can also track friendly fire, in order to locate the point of impact of friendly artillery fire, so as to issue necessary corrections.

    The contract for WLR Swathi (Plains) was signed with Bharat Electronic Limited (BEL) at a cost of over ₹990 crore. It is an indigenously designed WLR which is capable of locating guns, mortars and rockets firing own troops, thereby facilitating their destruction through Counter Bombardment by own firepower resources. This will enable troops to carry out their operational tasks without any interference from the enemy and also provide them safety against enemy fire. Induction is planned to be completed in 24 months.

    This project is a big opportunity for the defence industry to showcase its capability and will be a step in the direction of achieving the goal of 'Aatmanirbharta' in defence.
13. **Primary Radar for Airborne Early Warning and Control (PR for AEW&C):** LRDE is involved in development of Primary Radar (PR) for the Airborne Early Warning and Control (AEW&C) programme.
14. **Low-Level Transportable Radar (ASHWINI):** LLTR is a state-of-the-art, 4D active-array technology-based radar that performs multiple functions. This radar, being developed by LRDE, is aimed to provide airspace awareness regarding high manoeuvrable targets, in order to gain superiority.
15. **Development of Medium Power Radar (MPR): ARUDHRA:** This project is aimed to develop 4D Medium Power Radar (MPR) as a sophisticated multi-function sensor, being equipped with the advanced active array technology.

15.29 AWACS SYSTEMS (AIRBORNE WARNING AND CONTROL SYSTEM) OR AEW AND C (AIRBORNE EARLY WARNING AND CONTROL)

An AEW&C system is an airborne RADAR system, which is designed to detect aircrafts, ships and vehicles that are at long ranges and perform command and control of the battlespace during an air engagement by directing fighter as well as attacking aircraft strikes.

Phalcon

Phalcon, an Airborne Early Warning, Command and Control (AEWC&C) system, was manufactured by Israel. It is one of the most powerful systems of its kind in the world which provides real-time surveillance for a few hundred kilometres of territory and also renders services in command and control. It can pick up or track a low-flying aircraft, a missile and hence, provide advance warning after correlation. It will assist the Indian Air Force to maintain air superiority during a battle. It can pick up an incoming object in any weather condition, reportedly up to some 300 miles. On top of this, it can pick up all sorts of communications, be it from air, sea or land. All the information, so collected, can be easily conveyed live to the control centre of the headquarters.

This system has four sensors for coordinating with each other. If any sensor picks up an incoming object or enemy communication, the other sensors are automatically co-related and reconfirm it.

How is Phalcon Different from Other Airborne Early Warning Systems (AEWS)?

Most of the other AEWS are mechanically rotating antennas, or rotodomes that are mounted on an aircraft. On the other hand, Phalcon is with a stationary dome that is mounted on the aircraft and is based on an Active Phased Array Electronic Scanning Technology. It would be capable of continuously tracking any fast, high-manoeuvring objects in a lesser time period as compared to the rotodome-based AWACS. Being a full-fledged command and control centre, it can be deployed mid-air for directing the aircraft and providing them a picture of the whole battlefield. This feature enables them superiority over enemy fighters. Pakistan and China do not have Phalcon.

NETRA: A SURVEILLANCE TECHNOLOGY OF INDIA

n 2017, India has tested an air-to-air refuelling of the Embraer transport aircraft, which is equipped with NETRA. NETRA is the first indigenously developed, Airborne Early Warning and Control System (AEW&C), developed by DRDO. AEW&C is also popular with the name of eye-in-the-sky, due to its capability of long-range surveillance. The range of NETRA is 200 km, to detect aerial threats from incoming aircrafts and missiles with 240-degrees coverage. It can scan the area on both sides of the aircraft. For its multiple features, it is equipped with state-of-the-art active electronically scanned radar and secondary surveillance radar. It will use in electronic and communication counter measures and connect with line of sight and beyond line of sight data link. It is also equipped with a voice communication system and self-protection suit. Now, India stands at the fourth position in the world after the United States, Russia and Israel that have such technologies of their own.

Note: Currently, Indian Air Force is using three Israeli Phalcon AWACS (Airborne Warning and Control System) that have a range of 400 km and 360-degree coverage.

15.31 STEALTH TECHNOLOGY

Stealth technology represents a sub-discipline of military tactics and passive electronic counter-measures. It, thus, covers a range of techniques used by personnel, aircrafts, ships, submarines and missiles, so as to make them less visible (ideally invisible) to radar, infrared, sonar and other methods of detection. It is also known as LO technology (Low Observable technology). Two methods adopted for low observation are:

15.31.1 Non-Metallic Airframe

Dielectric composites show more transparency to radar. On the other hand, electrically conductive materials (like metals and carbon fibres) show reflection of electromagnetic energy incident on the material's surface. Composites may also contain ferrites in order to optimise the dielectric and magnetic properties of the material that may enhance its application.

15.31.2 Radar-Absorbing Material

Radar Absorbent Material (RAM), such as paints, is especially used on the edges of metal surfaces. While the material as well as thickness of RAM coatings is classified, the material employs absorption of radiated energy from some ground or air-based radar station into the coating, and then converting it to heat instead of reflecting it back.

15.32 ANTI-SATELLITE WEAPON

India had identified development of ASAT weapons, under the DRDO management, for destroying satellites in both LEO (2,000-km altitude above earth's surface) and the higher geosynchronous orbit, electronically as well as physically, as a thrust area in the DRDO's long-term integrated perspective plan (2012–2027).

15.33 INTERCEPTOR

An interceptor aircraft or simply an interceptor represents a type of fighter aircraft, which is specifically designed for intercepting and destroying enemy aircraft, particularly the bombers, which usually rely on great speed. Many such aircrafts were built in the period that started just prior to the World War II and ended in the late 1960s, since they became less important due to the shift in the strategic bombing role to Inter Continental Ballistic Missiles (ICBMs).

15.34 SONARS (SOUND NAVIGATION AND RANGING)

SONAR systems are used to detect an object under water with the help of ultrasonic sound waves. A range of Sonar systems, to serve the Indian Navy, have been developed by the DRDO, BEL (Bharat Electronics Limited), as well as the Indian Navy.

- **APSOH** (Advanced Panoramic Sonar Hull mounted)
- **HUMVAD** (Hull-Mounted Variable Depth)
- **HUMSA** (Follow on of the APSOH series; the acronym HUMSA represents Hull-Mounted Sonar Array)
- **NAGAN** (Towed Array Sonar)
- **PANCHENDRIYA** (Submarine sonar and fire control system)

Some other sonars like 'Mihir', which is an airborne sonar, are in trial phase, while work is being proceeded apace on a new generation of sonars. Since the Indian Navy's most powerful ships currently rely on DRDO-made sonars, they may be considered as one of the most successful achievements of the DRDO. The standard fit for the frontline naval ship would include the HUMSA-NG hull-mounted sonar, as well as the Na-gan towed array sonar. Mihir, a dunking sonar, is meant to be used by the Naval ALH (Advanced Light Helicopter). The Panchendriya, which is currently in production, is for the Kilo-class submarine upgrades.

15.35 TORPEDOES

TORPEDO is an **underwater missile system,** which is self-propelled. It is designed with an objective to be fired from a ship or a submarine. It can also be dropped into the water from an aircraft and can explode on reaching a target. The DRDO is currently engaged in the development of multiple torpedo designs, which include a lightweight torpedo. This lightweight torpedo has been accepted by the Navy and got clearance for production. The heavy weight wire-guided torpedoes are named **Varunastra** and **Thakshak.** The electrically powered Varunastra, reportedly, is now also in production. **Shyena** is an experimental advanced torpedo. It is developed by the Naval Scientific and Technological Laboratory, that is, India's DRDO wing.

15.36 ELECTRONIC WARFARE SYSTEM

Electronic Warfare (EW) systems use electromagnetic spectrum or directed energy for attacking the enemy or impeding enemy assaults via the spectrum. EW can target humans, communications, radar or other assets. It can be applied from air, sea, land and space via manned and unmanned systems. **'Samyukta'** is a mobile-integrated electronic system of India. DRDO, Bharat Electronics Limited, Electronics Corporation of India Limited and Corps of Signals of Indian Army have jointly developed it.

It is not limited to radio or a radar frequency, as it also includes IR, visible, ultraviolet and other portions of the EM spectrum, which are less used. Some other major features are self-protection, standoff, and escort jamming, and anti-radiation attacks. EW is a specialised tool, enhancing many air and space functions at several levels of conflict. Electronic warfare systems have following major subdivisions:

Electronic Attack (EA), for attacking personnel. It is equipped for degrading, neutralising, or even destroying enemy combat capability, inclusive of human life.

Electronic Protection (EP) includes actions that are taken for protection of personnel, facilities and equipment from any effects of friendly or enemy application of the electromagnetic spectrum, which degrade, neutralise, or even destroy friendly combat capability. Notably, Jamming is not a part of EP; instead, it is an EA measure.

Electronic Warfare Support (ES) includes actions tasked by or under direct control of an operational commander for searching, intercepting, identifying and locating sources of intentional and unintentionally radiated electromagnetic (EM) waves. Its major objectives are immediate threat recognition, targeting, planning, as well as conduct of future operations.

15.37 NTRO (NATIONAL TECHNICAL RESEARCH ORGANISATION) UNDER INTELLIGENCE ACT

The NTRO was created after the 1999 Kargil conflict, as a dedicated **'technical intelligence agency'**. It was finally constituted in 2004. It reports to the Prime Minister's Office (PMO) and the National Security Advisor (NSA). It functions under the National Security Advisor. It also includes National Institute of Cryptology Research and Development.

The Home Ministry issued a notification listing National Technical Research Organisation (NTRO) under the Intelligence Organisations (Restriction of Rights) Act, 1985.

Note: Intelligence Organisations (Restriction of Right) Act, 1985, aims to prevent leakage of information by intelligence agencies.
Various intelligence agencies, setup for the safety and security of India from various external threats, are Research and Analysis Wing (RAW), Intelligence Bureau, Directorate of Revenue Intelligence, Narcotics Control Bureau, etc.

RECENT NEWS

Cluster Munitions

Cluster munitions are weapons that can be delivered by rockets, missiles, and aircraft. They open in mid-air and disperse dozens and even hundreds of smaller submunitions, also called bomblets, over an area the size of a city block. Many submunitions fail to explode on initial impact, leaving duds that act like landmines, posing a threat to civilians for years and even decades.

15.38.2 Rudram Anti-Radiation Missile

- Successfully test-fired recently from a Suk-hoi-30 fighter aircraft.
- The missile has been developed by the DRDO.
- It has a strike range of around 100 to 150 km.
- It is the first indigenous air-to-ground missile developed by the DRDO, after the supersonic BrahMos, which has been developed jointly with Russia.
- The missile has been designed for Suppression of Enemy Air Defence (SEAD).
- The missile can be launched from a varying range of altitudes for destroying enemy surveillance radars, tracking and communication systems.

15.38.3 S-400

The S-400 Triumf is an air defence missile system developed as an upgrade of the S-300 series of surface-to-air missile system (SAM) designed by Russia. Rosoboronexport signed a contract with India to deliver S-400 missile system. It is the most dangerous operationally deployed modern long-range SAM (MLR SAM) in the world, considered much ahead of the **US-developed Terminal High Altitude Area Defense system (THAAD).**

S-400 can engage all types of aerial targets including aircraft, unmanned aerial vehicles (UAV) and ballistic and cruise missiles within the range of 400 km, at an altitude of up to 30 km. The system can simultaneously engage 36 targets.

Significance for India

From India's point of view, China is also buying the system. In 2015, China signed an agreement with Russia to purchase six battalions of the system. Its delivery began in January 2018.

China's acquisition of the S-400 system has been viewed as a 'game changer' in the region. However, its effectiveness against India is limited.

Russian Ambassador to India, Nikolai Kudashev recently confirmed that both India and Russia are 'committed' to completing their contract for the S-400 missile system, due to be delivered to India at the end of the year. He said both countries opposed **US sanctions on the issue.**

Issues

The S-400 deal could attract sanctions under US' CAATSA law. The US has already sanctioned China and Turkey over similar purchases.

India gets S-400 training equipment

- S-400 training equipment and simulators have arrived in India from Russia.
- However, there is a delay in the delivery of the second regiment of S-400 from Russia due to the ongoing war in Ukraine.

Concerns for India

There is the threat of U.S. sanctions under **CAATSA (Countering America's Adversaries Through Sanctions Act)** on India for imports from Russia. However, nothing is clear as of now.

What is CAATSA, and how did the S-400 deal fall foul of this Act?

- Countering America's Adversaries through Sanctions Act (CAATSA)'s core objective is to counter **Iran, Russia and North Korea through punitive measures.**
- Enacted in 2017.
- Includes sanctions against countries that engage in significant transactions with Russia's defence and intelligence sectors.

What sanctions will be imposed?

1. Prohibition on loans to the sanctioned person.
2. Prohibition of Export-Import bank assistance for exports to sanctioned persons.
3. Prohibition on procurement by United States government to procure goods or services from the sanctioned person.
4. Denial of visas to persons closely associated with the sanctioned person.

Significance of the deal

The S-400 decision is a very strong example of how advanced our defence and strategic partnership is, and how strong Indian sovereignty is, to choose its international partners, especially when it comes to issues of national interest and national security.

15.38.4 Countering America's Adversaries through Sanctions Act (CAATSA)

Countering America's Adversaries through Sanctions Act (CAATSA) is a United States federal law that imposed sanctions on Iran, North Korea and Russia. It was enacted in 2017 and includes sanctions against countries that engage in significant transactions with Russia's defence and intelligence sectors.

What sanctions will be imposed?

1. Prohibition on loans to the sanctioned person.
2. Prohibition of Export–Import bank assistance for exports to sanctioned persons.
3. Prohibition on procurement by United States Government to procure goods or services from the sanctioned person.
4. Denial of visas to persons closely associated with the sanctioned person.

15.38.5 Solid Fuel Ducted Ramjet (SFDR) Technology

The Indian Ministry of Defence recently demonstrated SFDR technology which was tested by DRDO at Integrated Test Range (ITR) Chandipur off the Odisha coast in India. The successful demonstration of the technology has provided the DRDO with a technological advantage that will enable the agency to develop long-range air-to-air missiles.

Benefits

- Ramjet powered missiles provide greater range and a higher average speed compared to missiles powered by solid propellants.
- Ramjet missiles use atmospheric oxygen rather than including an oxidiser as part of the solid motor.
- Ramjet missiles can also carry a bigger warhead as they do not have to carry an oxidiser.

15.38.6 Fractional Orbital Bombardment System (FOBS)

A Fractional Orbital Bombardment System (FOBS) is a warhead delivery system that uses an LEO towards its target destination. Just before reaching the target, it de-orbits through a retrograde engine burn. The idea behind FOBS is, a warhead is put into a stable orbit and it deorbits over the target.

If the target and the launch position is lined up and the warhead keeps going round, it will complete a circle. Obviously, with the earth moving during this, it is more of a spiral than a ring, but the horizontal movement is countered in such a way that the warhead still goes over the target.

Flight Tests of FOBS

In 1968, after its twentieth test the Soviet succeeded in FOBS. This FOBS project was called R-360.

Features

It granted unlimited striking range. It was capable of striking from any direction. It was smart to hide the target location till the payload was dropped. According to the Soviet Union, the FOBS were capable of trumping the anti-ballistic missiles of the US.

Outer Space Treaty

The Outer Space Treaty signed in 1967 stated that the signatories should not place nuclear weapons in the orbit around the earth. Even after the treaty, FOBS stayed in the space. The Soviet Union claimed that FOBS takes a partial orbit and can thus stay in space.

SALT II

The SALT II agreement was signed between the Soviet Union and the US in 1979. SALT stands for Strategic Arms Limitation Talks. The agreement prohibited the deployment of FOBS. The US Government did not ratify SALT II. However, the Soviet Union complied and decommissioned FOBS in 1983.

Why was FOBS ended?

One of the reasons is SALT II. Apart from this, the system faced technical disadvantages. The system demanded high level of energy to load a weapon into orbit. Also, it was less accurate than ICBM. ICBM stands for Intercontinental Ballistic Missile. ICBM was developed during Second World War. The countries that hold operational ICBMs are India, North Korea, USA, China, Russia, France and the UK.

Recent Developments

In 2021, Frank Kendal III (the US Secretary of Air Force) stated that the Chinese Government is developing and testing FOBS.

3.7 RaIDer-X

DRDO and the Indian Institute of Science in Bangalore have developed a new bomb detection device called **RaIDer-X.**

- It is an **explosives detection device.**
- It can **detect up to 20 explosives from a standoff distance of two metres.**
- **Developed by** the High Energy Material Research Laboratory (HEMRL) – an arm of the DRDO – in Pune and the Indian Institute of Science in Bangalore.
- It can also spot bulk explosives, even if, they have been concealed.

INDIAN DEFENCE JOINT EXERCISES OF NAVY, ARMY AND AIR FORCE

Indian Navy Joint Exercises

1. **Varuna:** France and India.
2. **SLINEX:** Sri Lanka and India.
3. **INDRA:** Bi-annual military exercise conducted by India and Russia.
4. **Exercise Malabar:** A bilateral of the United States and India.
5. **Simbex:** Indian and the Republic of Singapore.
6. **IBSAMAR:** India, Brazil and South Africa.
7. **KONKAN:** A bilateral naval exercise between Indian navy and the Royal Navy of Britain.
8. **AUSINDEX:** Indian and Australian navies' bilateral maritime exercise.
9. **Sahyog-kaijin:** Coast guards of Indian and Japan.
10. **Naseem Al Bahr:** India and Oman.

Indian Air Force Exercises

1. The joint India–UK air exercises are known as the **'Indradhanush'** or 'Rainbow'.
2. India-France air exercise **'Garuda'.**
3. **Avia Indra 2014:** India–Russia maiden aerial exercise.

Indian Army Joint Exercises

1. **Mithra Shakti exercise:** India and Sri Lanka.
2. **Hand-in-hand:** India and China.
3. **Exercise Shakti:** India and France.
4. **Exercise Nomadic Elephant:** India and Mongolia.
5. **Exercise Yuddh Abhyas:** Series of joint exercises between India and the USA since 2005.
6. **Surya Kiran:** India and Nepal.
7. **LAMITYE:** India and Seychelles.
8. **Prabal Dostyk:** India and Kazakhstan.

Applications

The device has various applications including narcotics, for local police, for customs and other detection agencies who need to detect various elements which may be explosive or non-explosive in nature.

Significance

Most of the recent terrorist attacks had explosives that were made from ***easily available ingredients like petrol and gelatine sticks rather than high-end materials*** and devices like RaIDer-X are incremental to hinder the threat from homemade explosives.

15.39 IRON DOME

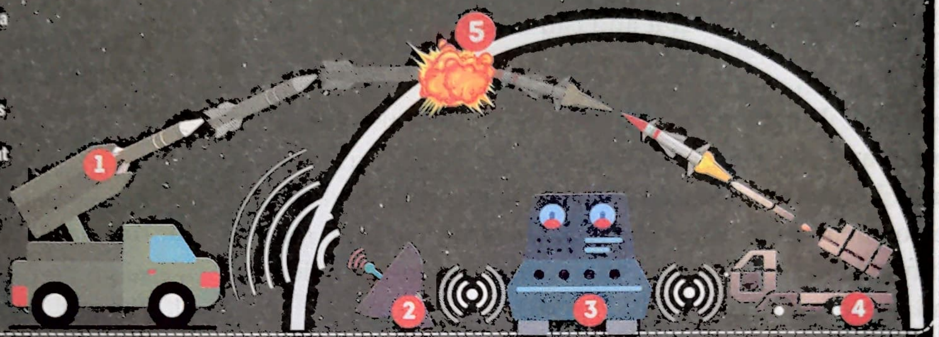
Refer Infographic – Iron Dome.

ISRAEL'S IRON DOME

WHAT IS IRON DOME DEFENSE SYSTEM?

- The Iron Dome is a highly advanced missile defense system developed and deployed by Israel.
- It is designed to safeguard civilian population and critical infrastructure from the threat of short-range rockets and artillery shells. With its impressive interception capabilities, the Iron Dome has become a crucial component of Israel's defense strategy.
- The Iron Dome was developed by Israeli defense companies, primarily Rafael Advanced Defense Systems, in response to the escalating rocket attacks faced by Israel.
- It represents a remarkable technological achievement and has gained international attention for its effectiveness in intercepting incoming projectiles.
- By understanding the purpose and capabilities of the Iron Dome, we can appreciate its significant contribution to enhancing the security and safety of Israeli citizens in the face of constant regional threats.

1. Enemy Rockets are Fired
2. Radar System detects Rockets and track
3. Control Systems estimates Rocket Impact Time (Battle Management and Control (BMC))
4. Launcher fires Missile to intercept
5. Missiles explodes near Rocket, destroying it



PURPOSE OF IRON DOME

- The primary purpose of the Iron Dome missile defense system is to protect civilian population and critical infrastructure from the threat of short-range rockets and artillery shells. It serves as a crucial line of defense, intercepting and destroying incoming projectiles that pose a danger to populated areas.
- The Iron Dome was specifically designed to address the unique security challenges faced by Israel, which has experienced frequent rocket attacks from neighboring territories. Its purpose is to minimize the impact of these attacks, reduce casualties, and safeguard civilian lives.
- By intercepting and neutralizing incoming rockets, the Iron Dome helps to maintain a sense of security among the population, enabling daily life to continue as normally as possible even during periods of heightened conflict. It aims to create a protective shield over targeted areas, providing a vital layer of defense against short-range threats.
- Furthermore, the Iron Dome serves as a deterrent, demonstrating Israel's commitment to protecting its citizens and deterring potential adversaries from launching attacks. Its effectiveness in intercepting and destroying projectiles not only saves lives but also provides a strategic advantage by mitigating the impact of rocket attacks.

INTERNATIONAL IMPACT OF IRON DOME

Protection of Israeli civilians: The primary purpose of the Iron Dome is to protect Israeli civilians from rocket attacks. By intercepting and destroying incoming projectiles, it has saved numerous lives and prevented significant damage to infrastructure. This has had a direct impact on the security and well-being of Israeli citizens.

Influence on Israeli defense strategy: The Iron Dome's success has influenced Israeli defense strategy by providing a sense of security against short-range rocket threats. This has given Israel more flexibility in responding to conflicts and potentially reduced the incentive for escalation.

Technological advancements: The development and deployment of the Iron Dome have showcased Israel's technological capabilities in missile defense systems. It has established Israel as a leader in this field, attracting international attention and admiration for its innovation and expertise.

Export of defense technology: The success of the Iron Dome has led to increased international interest in Israeli defense technology. Israel has exported its missile defense systems to several countries, including the United States, which has adopted some of its technology for its own missile defense programs. This has resulted in economic benefits for Israel and strengthened its defense industry.

Implications for regional stability: The effectiveness of the Iron Dome has influenced the strategic calculus of various actors in the region. It has provided Israel with a defensive advantage, potentially altering the balance of power and deterring adversaries from launching rocket attacks. This, in turn, may have contributed to stability by reducing the incentives for conflict escalation.

Inspiration for other countries: The success of the Iron Dome has inspired other countries to invest in missile defense systems and develop their own capabilities. It has demonstrated the value of such systems in protecting civilian populations and infrastructure, particularly in areas prone to conflict or regional tensions.

MISSILE DEFENSE SYSTEM (BY COUNTRIES)

USA
- Terminal High Altitude Area Defense (THAAD)
- Ground-Based Midcourse Defense (GMD) System
- Aegis Ballistic Missile Defense (BMD) system
- Patriot Advanced Capability (PAC-3) system

Russia
- A-135 Anti-ballistic Missile System
- S-300 Missile System
- S-400 Missile System

Israel
- Iron Dome
- Arrow-2
- Arrow-3
- 'David's Sling

China
- HQ-9
- KS series
- HQ-16
- HQ-19, HQ-26, and HQ-29, are being built.

India
- Ballistic Missile Defense (BMD) system
- Prithvi Air Defense (PAD)
- Advanced Air Defense (AAD) systems

Japan
- Aegis Ballistic Missile Defense (BMD) system
- Patriot Advanced Capability 3 (PAC-3)

S. Korea
- Terminal High Altitude Area Defense (THAAD) system

Saudi Arabia
- Terminal High Altitude Area Defense (THAAD) system

NATO
- NATO Missile Defense System
- NATO Integrated Air and Missile Defence (NATO IAMD)

16.1 CONCEPT OF ARTIFICIAL INTELLIGENCE

Artificial intelligence generally implies machines exhibiting traits of human intelligence. The important traits of human intelligence include observing, taking inputs from the observations, reasoning and rationalising, decision making, manipulations, learning from behaviour and patterns, communicating, analysing complex situations and performing tasks to achieve goals and targets.

At present, the 'subfields of AI' like machine learning, autonomous systems, natural language processing, robotics and artificial creativity are popular areas of research (**Table 16.1**).

TABLE 16.1 Thrust Areas of Contemporary AI Research

Machine Learning	This is the field in which computers are given the ability to learn without being explicitly programmed.
Autonomous Systems	A system that learns on its own to perform various tasks.
Language Processing	The field of interaction between machines and human languages.
Robotics	Robotics in entirety is not just AI but there is a field of AI-powered robots.
Artificial Creativity	Creativity using computer, e.g., Aiva is an AI-powered system, that can compose soundtracks. Google's project Magenta is all about AI applications in arts.

16.2 STRONG AI AND WEAK AI

There are two types of Artificial Intelligence: Strong Artificial Intelligence (SAI) and Weak Artificial Intelligence (WAI). What has been actually called strong AI is actually 'full AI'.

A full AI means a machine becoming capable of performing all intelligence tasks that a human being can perform. In this, a machine would not exhibit selective fragments of human intelligence but would rather behave like a human being in terms of consciousness.

Full AI is also known as 'artificial general intelligence'. Human beings reason, use strategy, solve problems, make judgements, use common sense, plan, learn, communicate and integrate all these to achieve their goals.

To test the artificial general intelligence of machines, some tests have been suggested. These are Turing Test (human and machine talk), Coffee Test (a machine can make coffee at your home), College Admission Test (a machine can enrol admission, join class and clear exam to get degree) and Employment test (machine is given an economically important job). There are different thrust areas of AI research those are mentioned in **Infographic – Artificial Intelligence.**

16.3 FROM ARTIFICIAL GENERAL INTELLIGENCE TO APPLIED AI

AI research began in the United States with particular interest in developing machines that could translate from Russian to English and vice-versa. This was in context of Cold War with the then Soviet Union.

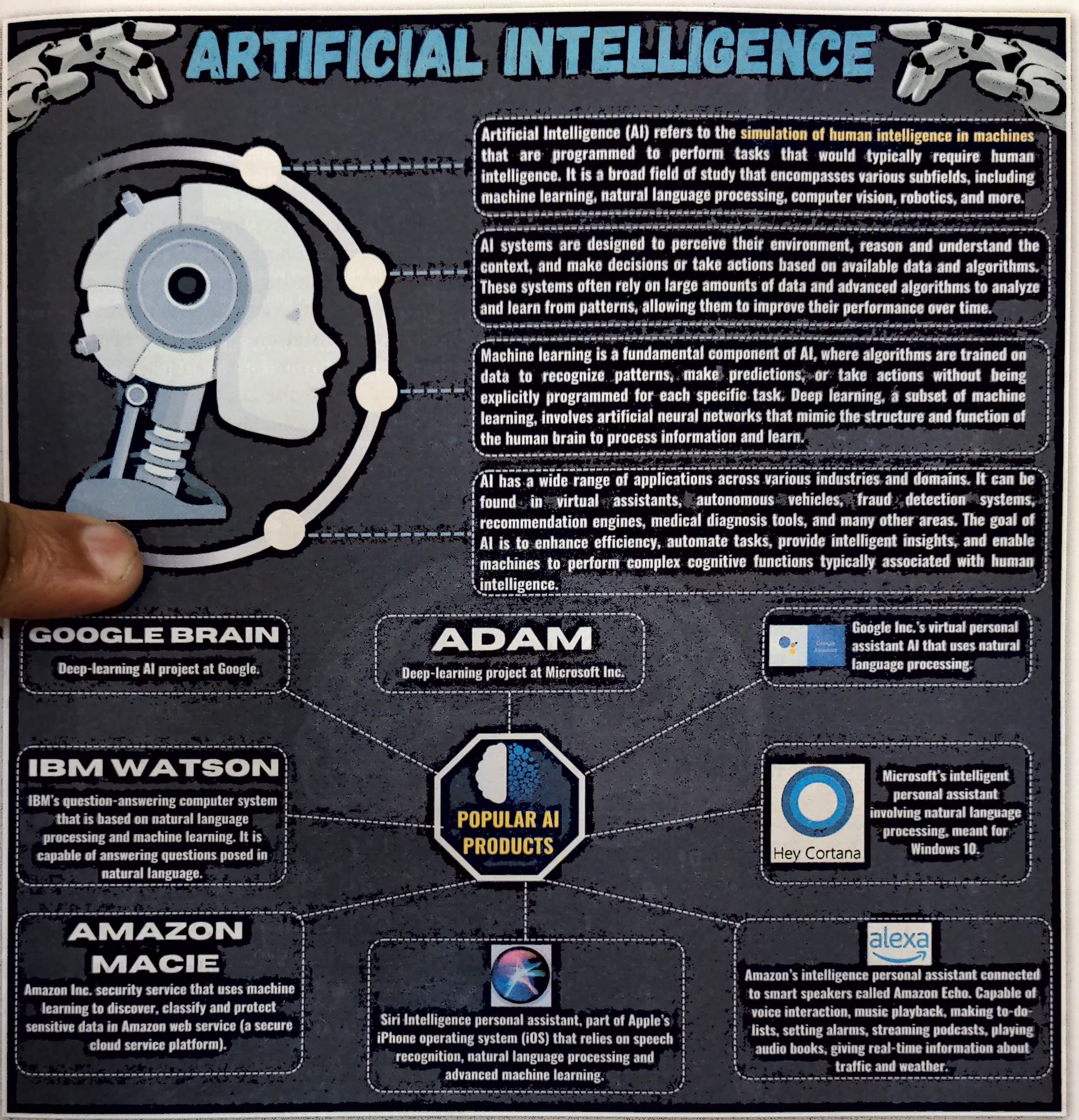
The revival of AI has taken place now with strides having been made in the applied aspect of Artificial Intelligence. The focus is now on developing AI for solving particular problems. Scientists are optimistic that this approach to AI is better than the top-down approach, in which the research initially was focussed on developing an artificial brain that would behave like a human brain.

The applications that are attracting maximum attention are machine learning, robotics, autonomous systems and natural language processing. Autonomous systems are systems with the ability to acquire or create content, interpret and develop knowledge from that content to make a decision on the basis of that interpretation.

They are now applied in the development of driverless cars, drones and fraud detection. Prominent examples of driverless cars include Waymo of Google S, model X and model 3. In February 2017, Dubai announced that its sky would soon see driverless drones for ferrying people. The passenger just needs to press a button and it takes off vertically.

Robotics is another area experiencing significant changes that have the potential to knock off many human relations. It has the potential to revolutionise areas of medicines, manufacturing, defence, personal assistants, hospitality industry, personal uses, etc.

It is machine learning as a subfield that has received attention for the advancements and research being undertaken. Machine Learning (ML) is based on the concept that a computer programme can learn and adapt to new data without human interference. It involves having an inbuilt source code or an algorithm, which would create a model that builds predictions around



ARTIFICIAL INTELLIGENCE

Artificial Intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to perform tasks that would typically require human intelligence. It is a broad field of study that encompasses various subfields, including machine learning, natural language processing, computer vision, robotics, and more.

AI systems are designed to perceive their environment, reason and understand the context, and make decisions or take actions based on available data and algorithms. These systems often rely on large amounts of data and advanced algorithms to analyze and learn from patterns, allowing them to improve their performance over time.

Machine learning is a fundamental component of AI, where algorithms are trained on data to recognize patterns, make predictions, or take actions without being explicitly programmed for each specific task. Deep learning, a subset of machine learning, involves artificial neural networks that mimic the structure and function of the human brain to process information and learn.

AI has a wide range of applications across various industries and domains. It can be found in virtual assistants, autonomous vehicles, fraud detection systems, recommendation engines, medical diagnosis tools, and many other areas. The goal of AI is to enhance efficiency, automate tasks, provide intelligent insights, and enable machines to perform complex cognitive functions typically associated with human intelligence.

POPULAR AI PRODUCTS

GOOGLE BRAIN

Deep-learning AI project at Google.

ADAM

Deep-learning project at Microsoft Inc.

Google Inc.'s virtual personal assistant AI that uses natural language processing.

IBM WATSON

IBM's question-answering computer system that is based on natural language processing and machine learning. It is capable of answering questions posed in natural language.

Microsoft's intelligent personal assistant involving natural language processing, meant for Windows 10.

AMAZON MACIE

Amazon Inc. security service that uses machine learning to discover, classify and protect sensitive data in Amazon web service (a secure cloud service platform).

Siri Intelligence personal assistant, part of Apple's iPhone operating system (iOS) that relies on speech recognition, natural language processing and advanced machine learning.

Amazon's intelligence personal assistant connected to smart speakers called Amazon Echo. Capable of voice interaction, music playback, making to-do lists, setting alarms, streaming podcasts, playing audio books, giving real-time information about traffic and weather.

the data it identifies. **Microsoft's project 'Adam' and Google's Google Brain are machine learning projects with a focus on deep learning,** which in turn is a subfield of ML.

Deep learning is the field that is trying to make machines learn using imitation of workings of the human brain in processing data and creating patterns for use in decision-making. In deep learning projects, **Natural Language Processing (NLP)** has emerged as an important area that would enable human machine interaction using speech and pattern recognition, understanding of machine in reading comprehension.

16.4 SOME RECENT NEWS OF AI

16.4.1 ChatGPT

- GPT stands for **Generative Pre-trained Transformer**, a kind of computer language model that **relies on deep learning techniques to produce human-like text-based inputs.**
- **It is a second AI already passed the Turing test (Human–machine talk). It is developed by** ChatGPT founder and OpenAI CEO **Sam Altman.** Eugene Goostman is a chatbot that some regard as having passed the first Turing test.
- The test is named after **Alan Turing**, the founder of the Turing Test and an English computer scientist, cryptanalyst, mathematician and theoretical biologist. Turing proposed that a computer can be said to possess artificial intelligence if it can mimic human responses under specific conditions.
- ChatGPT is an open AI chatbot that uses natural language processing to create human-like conversation. It is a **conversational chatbot powered by artificial intelligence.** The language model can respond to questions and compose various written content, including articles, social media posts, essays, code and emails.
- It is also a **neural network**, as a **large network of computers** can fine-tune its output of words based on feedback.
- ChatGPT is a powerful tool that can assist in the coding process. By using machine learning algorithms to analyse and understand code snippets, ChatGPT can generate accurate and efficient code solutions. While it does not replace human programmers, it can significantly improve productivity and coding accuracy.
- After the success of OpenAI's ChatGPT, several companies have launched their own versions of chatbots to grab a share of the market.
- **META, which loves to monopolise the 'Internet Chat' world, has launched its new chatbot called LLaMA.**
- **Generative AI**, like other forms of AI, learns to take actions from past data. However, it goes beyond simply categorising or identifying data and **creates brand new content, such as text, images, and computer code, based on that training.** One famous example of generative AI is ChatGPT.
- ChatGPT is insanely good at generating human-like responses to queries and solving problems through textual conversations. On the other hand, Google is really good at finding information, videos, images, products and almost anything on the internet.

GPT has been used in a variety of applications in chat systems, including:

1. **Generating responses for chatbots:** GPT can be used to generate coherent and believable responses for chatbots, allowing them to engage in natural and engaging conversations with users.
2. **Language translation:** GPT can be trained to translate text from one language to another, making it useful for chat systems that need to support multiple languages.
3. **Text summarisation:** GPT can be used to generate concise summaries of long texts, which can be useful in chat systems for providing quick and concise responses to users.
4. **Dialogue systems:** GPT can be used to power dialogues between chatbots and humans, allowing for more natural and engaging conversations.
5. **Sentiment analysis:** GPT can be trained to classify the sentiment of text, which can be useful in chat systems for detecting and responding to negative or positive sentiment.
6. **Knowledge base creation:** GPT can be used to create a knowledge base for a chatbot by generating responses to a large number of prompts and questions.

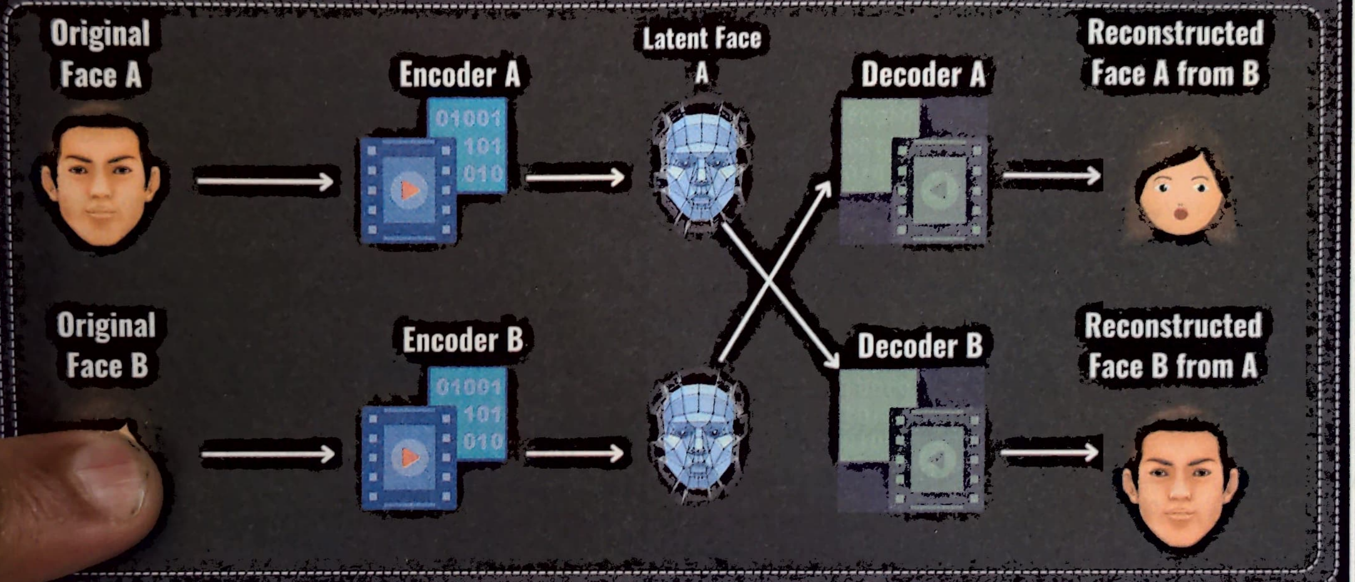
16.4.2 Deepfake

- **Deepfakes are digital media** – video, audio and images **edited and manipulated using Artificial Intelligence (AI)** to **inflict harm on individuals and institutions.**
- **AI-generated synthetic media or deepfakes** have clear **benefits** in certain areas, such as accessibility, education, film production, criminal forensics and artistic expression.
- It can be **exploited** (hyper-realistic digital falsification) **to damage the reputation**, fabricate evidence, defraud the public and undermine trust in democratic institutions with **fewer resources** (cloud computing, AI algorithms and abundant data).

(Refer Infographic – Deepfake)

DEEPFAKE

- Deepfakes are synthetic media created using AI techniques, particularly deep learning algorithms.
- They manipulate or generate realistic-looking images, videos, or audio recordings.
- Deepfakes use machine learning models to superimpose or swap faces, voices, or other characteristics onto existing content.
- They can deceive viewers into believing the manipulated content is genuine.
- Deepfakes are created by training neural networks, often using generative adversarial networks (GANs), on large datasets.
- Concerns surrounding deepfakes include misinformation, identity theft, and privacy violations.
- They can be used for spreading fake news, manipulating public figures' images or speeches, and creating non-consensual explicit content.
- Efforts are underway to develop detection techniques and policies to address the challenges posed by deepfakes.
- It is important for individuals to critically evaluate and verify the authenticity of media to mitigate the impact of deepfakes.



16.5 ARTIFICIAL INTELLIGENCE IN INDIA

India ranks third or fourth (depending on China's position in AI) in the size of AI clusters. India has already taken a lead in this regard, thanks to several AI start-ups. In this industry, the private sector has been vibrant.

According to a Canada based company's report, Global AI Report 2019, India stood at the ninth position in terms of the number of the AI specialists working in the field. The US, China and the UK topped the list.

However, the 2018 Union Budget, presented on 1 February 2018 signalled the government's intention to push for the development of machine learning and artificial intelligence.

The government allocated $480 Mn to fifth generation technology startups like artificial intelligence, machine learning (ML), Internet of Things (IoT), 3D printing and blockchain.

The NITI Aayog has even been asked to prepare a roadmap for a nationwide programme in artificial intelligence, including research and development of its applications.

The government mandated NITI Aayog to establish the National Program on AI with a view to guiding research and development in new and emerging technologies.

The government has also promised to offer incentives to start-ups and venture funds that undertake application-oriented research on artificial intelligence across key sectors, including banking, insurance, education, health, retail and transportation. The Department of Service and Technology is also looking into setting up centres of excellence that will push investments in 'research, training and skilling in robotics, artificial intelligence, digital manufacturing, big data analysis, quantum communication'. Different types of AI start-ups in India in the last few years are mentioned in **Table 16.2**.

TABLE 16.2 AI Startups in India

Active AI	Providing conversational banking service, aims to bring automation. Natural language processing and advanced machine intelligence are the focal areas.
Alndra Systems	Working on devices that can detect and identify people and objects.
Artificial	Deep learning.
Artivatic Data labs	Ingestible computing, which is used in making very tiny robots inside a capsule that can be ingested to collect data from the body.
Arya.AI	Neural network that will resemble human brain in functioning.
Fluid.AI	Facial recognition; present in problem-solving for banking, finance, web and government sectors.
Morph.AI	Chatbots for marketing and customer services.
Sig Tuple	In medical diagnosis, AI-powered visual analysis of medical data.

India's Defence Research and Development Organisation (DRDO) has developed a robot called Daksh, which can destroy life-threatening objects. Apart from applications like these, AI-powered robotics has been developed for entirely different uses.

It is estimated that AI will add 957 billion dollars to India's GDP by the year 2035 boosting India's annual growth by 1.3% points.

In 2019, NITI Aayog circulated the cabinet note to establish a cloud computing platform called AIRAWAT (Artificial Intelligence Research, Analytics and Knowledge Assimilation Platform).

In Budget 2019–20, the government has announced setting up of a National Sports Education Board under "Khelo India" project to prepare youth for new age skills, Artificial Intelligence, IoT, Big Data, 3D Printing, Virtual Reality etc.

Apart from these vibrant private sector clusters, India's Centre for Artificial Intelligence and Robotics (CAIR), a laboratory of the Defence Research and Development Organisation (DRDO), has developed a number of products that are powered by AI. Many of them are under development. Most of the products are in the areas of robotics, autonomous systems and intelligent systems that would do analyses without any human effort to give quick results.

CAIR PRODUCTS UNDER DEVELOPMENT

- AI technology for Net Centric Operations (AINCO), which will be a suite of technologies for creating knowledge base, information reception, handling, inferencing and event correlation.
- Knowledge Resources and Intelligent Decision Analysis (KRIDA) that would manage large-scale military moves by using knowledge base and data handling.
- RoboSen, a mobile robot system that would patrol, conduct recce and surveillance for armed forces, paramilitary forces and police. It can negotiate autonomously, avoiding obstacles and can give video feedback.
- A miniature unmanned ground vehicle, which is a man-portable robotic system for low intensity conflicts and surveillance in urban setting.
- Robots meant for logistics support that can walk six and four legs.
- Robots that can climb walls and flap wings for low-intensity conflicts.
- CAIR-ICR (Intelligent Character Recognition) system for the automated processing of handwritten entries.
- Snake Robot has been designed after analysis of gait of snake. It is used in search-and-rescue operations during natural calamities.

Interdisciplinary Cyber Physical Systems (IM-ICPS) has suggested the following four-tier framework for promoting AI research:

(a) ICON (International Centres of New Knowledge)
(b) CROSS (Centre for Research On Sub-Systems)
(c) CASTLE (Centre for Advanced Studies, Translational research and Leadership): focusing on development and deployment of application based research
(d) CETIT (Centre of Excellence in Technology Innovation and Transfer)

AI Research in India

Two-tier integrated approach to boost both core and applied research in AI is proposed:

CHATBOT ASKDISHA

The Indian Railways Catering & Tourism Corporation Limited (IRCTC) has powered voice-enabled **ASKDISHA Chatbot** to converse with customers in **the Hindi language**. The customers can now ask queries to ASKDISHA in Hindi by voice as well as text.

Keynote

- It is an **Artificial Intelligence-based chatbot**.
- It is a **special computer programme** designed to simulate conversation with users, especially over the Internet
- Initially launched in the English language in October 2018.
- Developed by **Indian Railway Catering and Tourism Corporation (IRCTC)**.
- The aim is **to resolve queries of railway passengers over the Internet pertaining to various services offered**.

Services provided

- Since its initial launch, passengers seeking help on the reservation of tickets, cancellation, enquiry of refund status, fare, PNR search, train running status, enquiry about retiring rooms and tourism products have been benefited.

1. **COREs (Centres of Research Excellence in Artificial Intelligence):** COREs will focus on core research of AI, and will take on the mantle of executing the responsibilities of both ICON and CROSS as per the IM-ICPS framework.
2. **ICTAI (International Centre for Transformational Artificial Intelligence):** ICTAIs will provide the ecosystem for application based technology development and deployment, and will take on the mantle of executing the responsibilities of both CASTLE and CETIT as per the IM-ICPS framework

Academic Institutes and Centres for AI

- Centre for Artificial Intelligence, IIT Kharagpur
- Centre for Artificial Intelligence & Robotics (CAIR), DRDO
- Robert Bosch Centre for Data Science and Artificial Intelligence, IITM
- The Artificial Intelligence Group, IISc, Bangalore
- Department of AI, IITH
- Academia-industry Collaboration on Artificial Intelligence
- Laboratory of Statistical Artificial Intelligence and Machine Learning (LSAIML), IITR

16.6 ADVANTAGES OF ARTIFICIAL INTELLIGENCE

1. There is utilisation of machines for taking on complex and stressed work that would else be undertaken by humans.
2. Machines finish the task sooner than a human if assigned with the same task.
3. They can be used in discovering unknown landscapes and outer space which is useful in our daily life.
4. As the task is being done by the machines, it causes less stress and injuries to humans.
5. Providing assistance to people who are visually and hearing impaired.
6. Through artificial intelligence, understanding complex software can be made easier.
7. Less number of errors and defects.
8. Time and resources are not wasted but smartly used to achieve the goal.

16.7 DISADVANTAGES OF ARTIFICIAL INTELLIGENCE

1. AI lacks human sensation; human qualities are ignored.
2. AI has the ability to replace a human job. This gives rise to humans feeling insecure of losing their jobs.
3. A machine can replace human capabilities and therefore, it can promote inferiority feelings among workers and staff.
4. There can be malfunctioning in artificial intelligence and there is possibility of the reverse happening as they are programmed to do so.
5. The younger generations may be corrupted.
6. No information filtration.
7. There can be misuse of such technology and thereby, causing a mass-scale destruction.

16.8 IS AI MOVING TOWARDS SUPER INTELLIGENT MACHINES?

The question is pertinent since the revival of intelligent machines has not just created euphoria over its potential benefits but has also given rise to fears that it would replace humans.

Even as robots are being made for performing simple human tasks that do not require complex problem-solving, there is a worry that planet Earth would turn into a place where humans would be slaves to machines that would be more intelligent than them. Artificial Intelligence is definitely trying to create machines and systems that will be more intelligent than their predecessors. So, this march of AI may lead to a future where machines are extremely intelligent but the fears may turn out to be exaggerated.

PROJECT BRAINWAVE

Microsoft has launched 'Project Brainwave', a deep-learning acceleration platform for real-time AI. It uses the massive field-programmable gate array (FPGA) infrastructure.

QUESTIONS AND ANSWERS

OBJECTIVE QUESTIONS

1. With the present state of development, Artificial Intelligence can effectively do which of the following? [UPSC (Pre) – 2020]

1. Bring down electricity consumption in industrial units.
2. Create meaningful short stories and songs.
3. Disease diagnosis.
4. Text-to-speech conversion.
5. Wireless transmission of electrical energy.

Select the correct answer using the code given below:

(a) 1, 2, 3 and 5 only
(b) 1, 3 and 4 only
(c) 2, 4 and 5 only
(d) 1, 2, 3, 4 and 5

Answer Key

1. (d)

17.1 HISTORICAL BACKGROUND OF ROBOTICS

In 1950s Karl Capek in his play *Rossum's Universal Robots* indicated the origin of a superior race that has intelligence similar to that of humans. Afterwards, Issac Asimov launched his robot laws and lastly Eric Elenberger, who is the father of robotics, pioneered real-time robots in the world.

A robot is an automatic control machine that substitutes human efforts, despite the fact that the robots may or may not look like in appearance to human being or performing function in the similar manner as that of human being. In the field of Science and Technology, robots deal with the design, manufacture and application and make use of computer for their manipulation and processing.

HISTORY OF ROBOTICS

In 1928, Japanese robot **GAKU TENSORU** was manufactured. In 1952, IBM's first commercial computer IBM701 was introduced, having a numerically controlled machine. The development of NC machine tools has been a turning point in the development of robotics. In 1954, George C. Devol invented the first truly modern digital Robot and this is called **UNIMATE**.

WABOT-1: was created by George Devol and constructed by Unimation, the first robot manufacturing company. Waseda University initiated the WABOT project in 1976, and in 1972 completed the WABOT-1, the world's first full- scale humanoid intelligent robot.

Then in 1956, John Macarty and Marwin Minsky coined the phrase AI. In 1973, **FUMULUS** Robot was manufactured by Germany. It was the first 6 degree of freedom of computer; those can move 360°. In 2000, HONDA built a humanoid robot **ASIMO**, walking like a human being.

17.2 DEFINITION

According to the Robot Institute of America, 1979, 'A robot can be defined as a reprogrammable, multifunctional manipulator designed to move parts, tools, material or specialised devices through various programmed motions for the performance of a variety of tasks'.

17.3 LAWS OF ROBOTICS

Sir Isaac Asimov gave the laws of robotics;

First Law A robot must not harm a human being or, through inaction, allow one to come to any harm.

Second Law A robot must always obey human beings unless it is in conflict with the first law.

Third law A robot must protect itself from harm unless that is in conflict with the first and/or second laws.

17.4 ROBOTICS IN INDIA

In ancient times, a robotic water organ was invented by Ctesibius, an Alexandrian inventor and mathematician. Already, the number of robots in use worldwide multiplied three-fold over the past two decades, to 2.25 million. Trends suggest the global stock of robots will multiply even faster in the next 20 years, reaching as many as 20 million by 2030. Due to automation, there is a major impact of robotics on the economy of the world. **'Automation'** pertains to robots in which a computer programme dictates its actions. A robot comprises a repertoire of sensors and actuator, together with a **'Brain'** (a microprocessor) and communication capability.

Developments related to robotics from the **NISTEP (National Institute of Science and Technology Policy) 2030 report:**

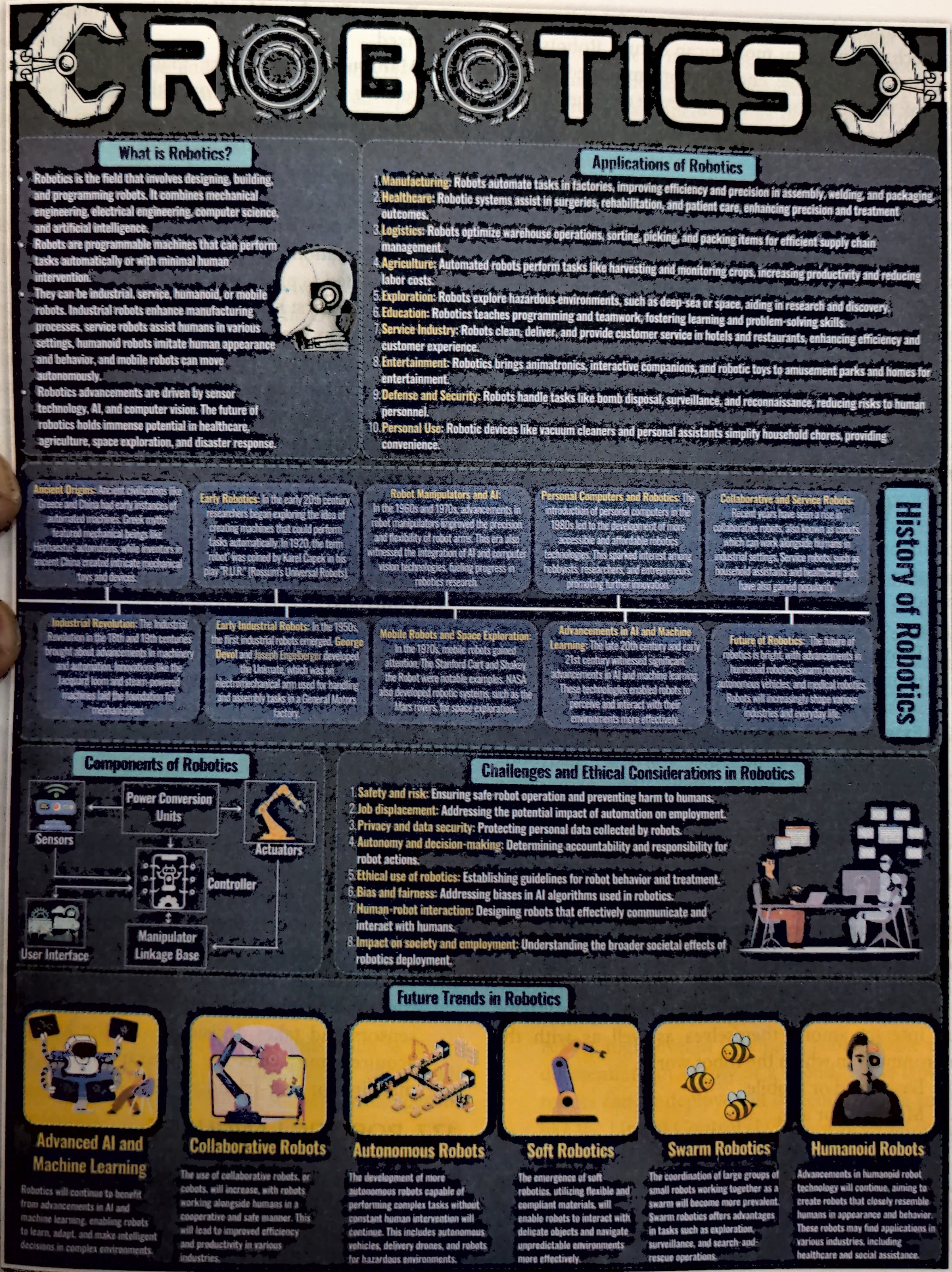
- By 2013–2014 – Agricultural robots
- By 2013–2017 – Robots that care for the elderly people
- By 2013–2020 – Nano robot
- By 2017 – Medical robots to perform low-invasive surgery
- By 2017–2019 – Household robots (cleaning of house, keep eye on intruders, etc.)
- By 2035 – Completely autonomous robot soldiers on the battlefield

(Refer **Infographic – Robotics**)

17.5 COMPONENTS OF ROBOTS

17.5.1 Structure

It is mostly mechanical and usually referred to as a kinematic (Kinematics as a field of study is often referred to as the 'geometry of motion') chain formed of links, actuators and joints, which can allow one or more



ROBOTICS

What is Robotics?

- Robotics is the field that involves designing, building, and programming robots. It combines mechanical engineering, electrical engineering, computer science, and artificial intelligence.
- Robots are programmable machines that can perform tasks automatically or with minimal human intervention.
- They can be industrial, service, humanoid, or mobile robots. Industrial robots enhance manufacturing processes, service robots assist humans in various settings, humanoid robots imitate human appearance and behavior, and mobile robots can move autonomously.
- Robotics advancements are driven by sensor technology, AI, and computer vision. The future of robotics holds immense potential in healthcare, agriculture, space exploration, and disaster response.

Applications of Robotics

1. **Manufacturing:** Robots automate tasks in factories, improving efficiency and precision in assembly, welding, and packaging.
2. **Healthcare:** Robotic systems assist in surgeries, rehabilitation, and patient care, enhancing precision and treatment outcomes.
3. **Logistics:** Robots optimize warehouse operations, sorting, picking, and packing items for efficient supply chain management.
4. **Agriculture:** Automated robots perform tasks like harvesting and monitoring crops, increasing productivity and reducing labor costs.
5. **Exploration:** Robots explore hazardous environments, such as deep-sea or space, aiding in research and discovery.
6. **Education:** Robotics teaches programming and teamwork, fostering learning and problem-solving skills.
7. **Service Industry:** Robots clean, deliver, and provide customer service in hotels and restaurants, enhancing efficiency and customer experience.
8. **Entertainment:** Robotics brings animatronics, interactive companions, and robotic toys to amusement parks and homes for entertainment.
9. **Defense and Security:** Robots handle tasks like bomb disposal, surveillance, and reconnaissance, reducing risks to human personnel.
10. **Personal Use:** Robotic devices like vacuum cleaners and personal assistants simplify household chores, providing convenience.

History of Robotics

Ancient Origins: Ancient civilizations like Greece and China had early instances of automated machines. Greek myths featured mechanical beings like Hephaestus' automatons, while inventors in ancient China created intricate mechanical toys and devices.

Industrial Revolution: The Industrial Revolution in the 18th and 19th centuries brought about advancements in machinery and automation. Innovations like the Jacquard loom and steam-powered machines laid the foundation for mechanization.

Early Robotics: In the early 20th century, researchers began exploring the idea of creating machines that could perform tasks automatically. In 1920, the term "robot" was coined by Karel Čapek in his play "R.U.R." (Rossum's Universal Robots).

Early Industrial Robots: In the 1950s, the first industrial robots emerged. **George Devol** and **Joseph Engelberger** developed the Unimate, which was an electromechanical arm used for handling and assembly tasks in a General Motors factory.

Robot Manipulators and AI: In the 1960s and 1970s, advancements in robot manipulators improved the precision and flexibility of robot arms. This era also witnessed the integration of AI and computer vision technologies, fueling progress in robotics research.

Mobile Robots and Space Exploration: In the 1970s, mobile robots gained attention. The Stanford Cart and Shakey the Robot were notable examples. NASA also developed robotic systems, such as the Mars rovers, for space exploration.

Personal Computers and Robotics: The introduction of personal computers in the 1980s led to the development of more accessible and affordable robotics technologies. This sparked interest among hobbyists, researchers, and entrepreneurs, promoting further innovation.

Advancements in AI and Machine Learning: The late 20th century and early 21st century witnessed significant advancements in AI and machine learning. These technologies enabled robots to perceive and interact with their environments more effectively.

Collaborative and Service Robots: Recent years have seen a rise in collaborative robots, also known as cobots, which can work alongside humans in industrial settings. Service robots, such as household assistants and healthcare aids, have also gained popularity.

Future of Robotics: The future of robotics is bright, with advancements in humanoid robotics, swarm robotics, autonomous vehicles, and medical robotics. Robots will increasingly shape various industries and everyday life.

Components of Robotics

Sensors
Power Conversion Units
Actuators
Controller
User Interface
Manipulator Linkage Base

Challenges and Ethical Considerations in Robotics

1. **Safety and risk:** Ensuring safe robot operation and preventing harm to humans.
2. **Job displacement:** Addressing the potential impact of automation on employment.
3. **Privacy and data security:** Protecting personal data collected by robots.
4. **Autonomy and decision-making:** Determining accountability and responsibility for robot actions.
5. **Ethical use of robotics:** Establishing guidelines for robot behavior and treatment.
6. **Bias and fairness:** Addressing biases in AI algorithms used in robotics.
7. **Human-robot interaction:** Designing robots that effectively communicate and interact with humans.
8. **Impact on society and employment:** Understanding the broader societal effects of robotics deployment.

Future Trends in Robotics

Advanced AI and Machine Learning

Robotics will continue to benefit from advancements in AI and machine learning, enabling robots to learn, adapt, and make intelligent decisions in complex environments.

Collaborative Robots

The use of collaborative robots, or cobots, will increase, with robots working alongside humans in a cooperative and safe manner. This will lead to improved efficiency and productivity in various industries.

Autonomous Robots

The development of more autonomous robots capable of performing complex tasks without constant human intervention will continue. This includes autonomous vehicles, delivery drones, and robots for hazardous environments.

Soft Robotics

The emergence of soft robotics, utilizing flexible and compliant materials, will enable robots to interact with delicate objects and navigate unpredictable environments more effectively.

Swarm Robotics

The coordination of large groups of small robots working together as a swarm will become more prevalent. Swarm robotics offers advantages in tasks such as exploration, surveillance, and search-and-rescue operations.

Humanoid Robots

Advancements in humanoid robot technology will continue, aiming to create robots that closely resemble humans in appearance and behavior. These robots may find applications in various industries, including healthcare and social assistance.

degrees of freedom (in particular, any of the directions in which independent motion can occur). Robots used as manipulators have end effectors mounted on the last link that could be a welding device or a mechanical hand used to manipulate the environment.

17.5.2 Essential Components of Humanoid

- Hands of robots are called **End effectors.**
- Arm of robots are called **Manipulators.**
- End effectors are termed as **grippers**, which consist of just fingers that open for picking and close for releasing a variety of small objects. It may be a vacuum gripper where large electronic components such as car and windscreen are manipulated.
- **Actuators** are the robot's muscles and joints.

.3 Planning, Controls and Sensing in Humanoid Robots

The robots' planning and control are focussed on path planning, self-collision, detection and avoidance of obstacles by collecting information from the three sensors.

1. **Proximity Sensors:** Used in the measurement of relative distance in the surroundings between the sensors and objects.
2. **Exteroceptive sensors:** These sensors assist in interacting with the outer world by providing information to robots about the surrounding environment.
3. **Proprioceptive sensors:** Their usage is done in sensing humanoid robots' position, orientation and speed.

17.6 ROBOTICS SYSTEMS AND ROBOT ANATOMY

A robot is a system, as it combines many subsystems that interact among themselves as well as with the environment in which the robot works.

1. Base: fixed or mobile
2. Manipulator arm
3. End effector
4. Drives or actuators
5. Controller
6. Sensors
7. Interfaces

1. **Base – Fixed or Mobile:** Without wheel robot is fixed.
2. **Manipulator Arm:** The manipulator is located relative to the ground on either a fixed or on a movable base. In 6 degrees of freedom robot, the first three links of the manipulator constitute the body and they help to place the end-effector at a desired location inside its work environment. At the end of manipulator, the wrist is located. Three rotational freedoms of the wrist are usually designated as pitch, yaw and roll.
3. **End-effectors:** Robot's end effector is the grip-per of end-arm tooling mounted on the wrist of the robot manipulator. It is designed to grip materials, parts and tools to perform specific tasks. Example: mechanical gripper, lifting gripper, vacuum cups, magnetic grippers, tool handling grippers, special grippers.
4. **Actuator:** Actuator is a component that converts energy extracted out of fluid, i.e., electric current to mechanical work. It is responsible for moving or controlling the system.
5. **Controller:** It acts as the brain of a robot. Based on the signal from the controller, manipulators do its work.
6. **Sensors:** Sensor is a transducer used to make measurements of physical variables. By this sensor, robot receives necessary manipulation, sends signals and interacts with peripheral equipment. It is of two types: Contact sensors and Non-contact sensors. Contact sensors respond to physical contact, such as touch, slip, force and torque. Non-contact sensors are relying on the response of a detector to variations in acoustic or electromagnetic radiation. Proximity and vision sensors are examples of non-contact sensors.
7. **Interfaces:** It acquires information from the surrounding environment by means of external sensors and takes decisions with the knowledge acquired and sends the necessary signals to the machine for user-friendly work.

17.7 ROBOTIC LANGUAGE

Robotic languages have been developed to control the motions of robots having different structures and geometrical capabilities. These are broadly classified into: First-generation language, Second-generation language and World modelling and task-oriented object level language.

The programme and control method robots are actuated through software running on an operating system in which manipulation of data takes place. Monitor mode, execute mode and editor mode are the three basic modes of software to operate the systems.

17.8 ROBOTIC OPERATION SYSTEM

Robot Operating System (ROS) is a collection of software frameworks for robot software development, providing operating system. Robotic Operating System provides standard operating system services such as implementation of commonly used functionalities, message passing between processes, hardware abstraction, low-level device control and package management. Running sets of Robotic Operating System-based processes are represented in a graph architecture where processing takes place in nodes that may receive, post and multiplex sensor, control, state, planning, actuator and other messages. Despite the importance of reactivity and low latency in robot control, Robotic Operating System, itself, is not a Real-time Operating System, though it is possible to integrate Robotic Operating System with real-time code.

Software in the ROS Ecosystem can be categorised into three groups:

- **Language and platform:** It is an independent tool used for building and distribution of ROS-based software;
- ROS client library implementations such as roscpp, rospy and roslisp;
- Packages containing application like related code, which uses one or more ROS client libraries.

17.9 APPLICATIONS OF ROBOTICS

17.9.1 Defence

- Robots that could make decisions, such as to fire upon a target without any human commands and to replace the human soldiers in dangerous missions.
- Many of the most advanced Indian Defence Technologies in time to come would comprise robots. As is evident, for supporting military operations through land, sea, air, the US deployed thousands of robots in Iraq and Afghanistan.
- Unmanned aerial, ground or underwater vehicles often achieve intelligence gathering. Deployment of unmanned autonomous vehicles for the purpose of reconnaissance such as detection of anti-ship mines in littoral waters, coastal waters monitoring for adversaries such as pirate ships and accurate air strikes on evasive targets.
- Boston Dynamic's robotic **'Big Dog':** It was created in 2005 by Boston Dynamics with Foster-Miller, the NASA Jet Propulsion Laboratory, and the Harvard University Concord Field Station. It looks similar to a big dog and is a remote-controlled robot; thereby, enabling soldiers for transportation of heavy equipment over narrow steep foothills, ice, and dense forest areas.
- **'DARPA'** has developed six-legged robots, which are an all-terrain and all-weather robots having the capability of passing intelligence from far-flung areas to the control stations with the help of wireless communications.
- Robot-powered exoskeletons will make human soldiers with super-human strength.
- Explosive-disposal robots named as 'Talon' are keeping soldiers away from the physical danger by destroying mines and ultimately saving human life.
- **'Andros II'** and **'Mini-Andros'** are deployed for their usage in bomb squads worldwide; they can also monitor in the dark and further helps in the defusing or detonating bombs without the risk of human life.
- **'Daksh'** is an electrically powered and remote-controlled robot. It is one of the most current military robots of India. It is used to locate, handle and destroy risky objects safely and can even climb stairs. The main role of this military robot is to recover improvised explosive devices.
- A very high level of intelligent robot enable us to differentiate an enemy or a friend. These types of robots can be deployed in difficult warfare zones, like the Line of Control (LOC) – a step that would help avert the loss of human lives.
- The *'Robotic Soldier'* would be at the front end in the battlefield and the human soldiers would be assisting him from far away.

17.9.2 Manufacturing

- From cars to computers, automation and robotics play a vital role in the production of different types of consumer goods. Automotive and appliance manufacturers and bottling plants have increased the usage of industrial robots in their assembly lines. Robots make manufacturing processes more efficient and consume less time by assembling the product faster and making the process more reliable.
- They can work in different conditions and also do heavy lifting. Robots reduce the physical size of technological machinery, which is shrinking now at an amazing rate.
- Today, various manufacturing industries in the world have the most innovative technologies and nanotechnologies demand for the requirement of high human precision. For the creation of synthetic diamond, there is requirement of human hands, which can consistently place one carbon molecule on another but with the usage of robots, it can be more accurately done.

17.9.3 Medicine

- Since the 1980s, robots are helping the doctors in the removal of gallbladders, hysterectomies and repairing knee ligaments.
- Through little and better robotic tools and software systems at the time of surgery, there is a requirement for smaller incision wounds and shorter duration under anaesthesia for the patients than with conventional methods of surgery. This will result in the reduction of healing times, lesser pain, reduced infection risk and lesser loss of blood so there is no need of blood transfusion.
- Through remote surgery (telesurgery), rural patients can be operated by the doctors in the city, thereby, decreasing the costs of transportation and increasing the alternatives for both patients and doctors. In the current world of surgery, good doctors are limited to a geographic location and population and hence, are unable to perform at a broad range of services.
- In case of bio-terrorist attack or an epidemic, medical robotic immune personnel can be the best alternative solution for the curing of infected individuals.
- Remote surgery will also be helpful to provide medical care more quickly than under current conditions.
- Robotic limb can also be helpful to soldiers injured on the battlefield; whereby, the soldier, after some practice or recouping from the injury, can again be sent to war, depending on the gravity of the injury or there can be a robot who can replace the soldier on ground.

17.9.4 Disaster Preparedness, Response and Relief

- At the time of any national disasters, roads may be ruined or flooded and telephone or Internet lines may not work. Thus, to help in these types of situation, Denel Dynamics has established a 'homing pigeon' UAV, which can fly and supply the required relief material quickly to the disaster-prone area and return to base without any human intervention, being faster than conventional carriers.
- At the time of bio-terrorist or biochemical assaults, the said UAVs can possibly deliver face masks or antidotes without risking a pilot's health. The usage of UAVs could create self-contained networks of communications.
- Currently, we are using satellite communication networks. After huge explosions, in weather and other conditions, the existing technology could be useless. Swiss Institute of Technology in Lausanne [École polytechnique federale de Lausanne (EFPL)] has planned a group of 'Micro Air Vehicles', which have the capability of autonomously establishing an emergency wireless network, thus, connecting ground users in a disaster area.
- After an earthquake, or tsunami or any missile attack, rescue through the assistance of robots will be the country's most effective course of action. Cloud burst in Uttarakhand had claimed many lives and wrecked havoc. In this area, rescue operations took lot of time, which was crucial for the stranded people waiting for help. In this type of situation, robots can quickly find trapped victims, send their images to rescuers in real time without needlessly putting responders at risk and thus save many innocent lives. Taking a clue from this

natural calamity, we should now be prepared with a Disaster Preparedness, Response and Relief plan, incorporating robots to carry out relief operations.

17.9.5 Humanoid Robots

The development of Honda's ASIMO and Sony's SDR-3X and now the more advanced SDR-4X refers to robots having the human resemblance. These humanoid robots, with remarkable grace, walk on their two feet, similar to the human-walking movements. SONY engineers have provided SDR-4X with advanced features such as the ability to remember and emotions, recognition from facial features, besides better voice and speech recognition technology.

TABLE 17.1 World's Important Humanoid Robots

S. No.	Humanoid Robots (Company)	Features
	SOPHIA (Hanson Robotics)	• most advanced humanoid robot who made her debut in 2016
	ATLAS (Boston Dynamics)	• developed in 2013 with a prime focus on locomotion, first walking in the lab, then walking on every type of unstable terrain, and performing some sick Parkour tricks
	AMECA (Engineered Arts)	• world's most advanced, most realistic humanoid robot created in 2021.
4	Nadine (Kokoro)	• an empathetic robot developed in 2013 responds to greetings, makes eye contact, and remembers all comments and conversations with her
5	ASIMO (Honda)	• created for search and rescue missions. • it responds to various questions by nodding and speaking in different languages and can recognize almost ten different faces and address them by name.

17.9.6 Agriculture Robot

The advantage of Agri-robot, which is developed in India, is that it can become an admirable agriculture aid for farmers. The high labour cost and the increased need of assisted living have led to the development of the service robotics market. This automated system will be the most essential appliance for our society as India is the second largest producer of vegetable crops in the world. The developed model avoids the wastage of precious seeds, as it is designed to pick and drop only one seed at an instant; consequently, it increases the percentage of germination, which leads to profit for the farmers, who are the backbone of our nation's economy. As a result, the farmers/society will be the beneficiaries. The concept of automation incorporated in the intended system avoids the labour cost and reduces the process time. Consequently, it is cost-effective.

17.9.7 Robotics for Environmental Monitoring

Scientists, allowing new perspectives and a better understanding of the planet and its environmental processes, are increasingly utilising robotic systems as fundamental data-gathering tools. In the past, their use in environmental sciences has been relatively subtle and not highly publicised, but some disruptive events (such as the 2010 eruption of volcanoes in Iceland, the massive oil spill in the Gulf of Mexico from the Deepwater Horizon incident and the tragic 2011 earthquake and tsunami in Japan) have reinforced and publicised the importance and abilities of robotic systems to efficiently and precisely measure and potentially reduce environmental events at scales that were never possibly thought earlier.

With rising public awareness of robots, collecting pertinent scientific information and environment interaction, there are rising new opportunities for major environmental monitoring.

The benefit of robotics usage in environmental sciences is allowing the monitoring of events and sampling that is impossible or dangerous to undertake by humans.

In one article, which refers to 'Volcanic Environments', there is discussion of their long experience history in the terrestrial robotic systems application and development for active volcano monitoring. They emphasise the requirements of system and the further challenges for the collection of scientifically relevant data in these hostile environments. With this in situ volcanic monitoring process capability, volcanologists are now empowering for the better understanding and investigating the precursor of volcanic eruptions, further allowing a more precise activity prediction.

The arrangement of navigation and chemical sensors for estimating the environmental parameters such as wind speed and direction can be measured with the usage of robotics. A single robotic vehicle's capability in capturing the temporal and spatial dynamics like harmful cyanobacterial blooms of developing aquatic processes can be a serious public health issue.

In spite of the unbelievable developments of research and commercially available robotic systems, regulators and authorities are still inflicting considerable restrictions on scientists in the usage of these systems for monitoring of environment, mainly near populated areas.

17.10 CHALLENGES OF ROBOTICS IN INDIA

Among the many challenges that has plagued the field of Robotics in India, the primary among them have to do with the high capital cost, talent availability and procurement of hardware components. Robotics is a multidisciplinary field with four to five engineering subjects; so it's difficult to gain expertise in this field. There is a scarcity of skilled faculties to teach robotics. Except a few regions and institutions in the country, Robotics as a subject is not introduced in engineering courses.

17.11 INDIA'S ADVANCEMENT IN ROBOTICS

- R&D organisation initiated in India the development of mini robots and about 101 master slave manipulators were made till April 1987.
- BARC (Bhabha Atomic Research Centre), Bombay, supported research projects on tele-robots.
- The Department of Electronics of Government of India also successfully initiated a project of fins welding of the turbine blades at BHEL (Bharat Heavy Electronics limited), Hyderabad, during 1994–97.
- By 2013–14, agricultural robots were introduced in Indian agricultural sectors.
- From the information in **National Institute of Science and Technology Policy (NISTEP)** 2030 report, it is said that, by 2013–20, our researchers will introduce nano robots in medical sectors for surgery.
- SASTRA's (It is a robotic private limited company in Kochi, Kerala) SCARA robot can perform repetitive tasks, for uses such as moving products, milling, 3D-paintings and is being used by Bosch to test touch screens. **'AcYut' is India's first indigenously developed humanoid robot.**
- **'Daksh'** is an electrically powered and remotely controlled robot used for locating, handling and destroying hazardous objects safely in military war. It was developed by DRDO in December 2011 and by 2035, DRDO is going to have completely autonomous robot soldiers on the battlefield.
- The premier institution in India for Robotic research is **Centre for Robotics and Mechatronics, Kanpur.**

Mitra Robot

Mitra Robot is a Humanoid Robot designed and developed by the Indian start-up company Invento Robotics. Mitra Robot made its first appearance in November 2017 at the Global Entrepreneurship Summit in 2017.

The five feet tall robot, Mitra-2 is India's first humanoid robot built and designed to engage in hospitality management and workplace productivity.

- Its body is made of fibreglass equipped with a touchscreen with battery backup of up to 8–10 hours. This robot has facial and speech recognition those are designed to recognise speech in multiple languages.
- Mitra-3 is an improved version of Mitra which has three degrees of freedom (shoulder, elbow, and finger movements) so it can welcome guests with a 'namaste' and also has other hand gestures.
- Mitra Robot is utilised in various disciplines like banks, wedding, hotels, malls, airports, cinema halls and hospitals, etc.

Shalu Robot

Robot Shalu is a multilingual, social and educational humanoid robot made-up of waste material (aluminium, plastic, cardboard, wood, newspapers, and other things readily available in the local market), and can speak 47 languages developed by Dinesh Kunwar Patel. During the Corona pandemic, it spread a message "Wear your mask, keep physical distance and follow government guidelines".

She can recognise people and remember them as well as identify many common objects. She can not only understand human emotions like anger, happiness, laughter, jealousy, etc. but can also behave accordingly. The total weight of the robot is only 4 kg as it has only an upper body.

Robot Shalu is dedicated to Indian daughters towards Beti Bachao Beti Padhao mission, and this creation is a tiny step towards Atmanirbhar Bharat and Digital India Mission.

- Various IITs are offering courses in computer sciences with specialisation in A.I., which is an integral part of robotics.
- Centre for A.I. and Robotics in Bengaluru has developed a **'Chatur Robot'** – an intelligent robot with vision sensor, which can pick up objects in visual field.
- Scientists from University of Ulster and IIT-Kanpur have teamed up to investigate how to develop intelligent robotics devices to help people with severe disabilities, making them achieve greater independence.
- In AIIMS New Delhi, there is successful performing of **robotic surgery** in which the thymus gland was removed from a patient suffering from 'Myasthenia Gravis' (a progressive muscular weakness disease that can sometimes be life threatening). Thymectomy is the removal of thymus gland early in the course of the disease.
- India is emerging as a hub for industrial robots and many Americans, Koreans and Japanese are using them.
- Ahmedabad-based 'Grid Bots' launched **'Robo Grad'**, a robot that can clean homes and keep an eye on intruders.

17.12 DISADVANTAGES

- Employing a robot in factories has fewer limitations, as the humans performing the tasks require creativity, decision-making skills, time for adaptation and learning the job. Thus, the employees having no experience in dealing with robots require training programmes to interact with the new robotic equipment, which will take time and cost huge amounts of money in the financial input.
- The robot helps the workers' protection from various hazards. But, they themselves can create safety problems, thereby causing new danger, which need to be taken into consideration.
- The preference of industries in the utilisation of robots instead of human workers will increase unemployment rate, hence, creating social disturbances.
- Robots are costly in terms of both production and purchasing. Robots in the home could also cause conflicts because not everyone is going to financially be able to own it. Due to regular use of robots, the humans will become physically lazy, which might lead to many diseases.
- The major drawback of a robot is that it has no emotions. So, it cannot understand human values, ethics and cannot take decision based on philosophical or social values. It has no thinking power analysing of what is wrong or right and a day will come, when robots will be more powerful than humans and rule the whole world.

17.13 BIONIC MAN

Rex Bionics Limited is the global technology leader in robotic exoskeletons (Rex). Uniquely, Rex provides independent mobility to wheelchair users and other mobility-impaired persons, using advanced robotic technology, custom-designed electromechanical actuators, precision engineering and specialised networking systems.

For more detail refer **Infographic – Bionic Man and Sophia**.

17.14 SOPHIA

'Sophia' is a **social humanoid robot** developed by Hong Kong-based company, Hanson Robotics. With the ability to display more than 62 facial expressions, Sophia has participated in many high-profile interviews. In October 2017, Sophia was also given **citizenship of Saudi Arabia** – the first robot to receive citizenship of any country.

(Refer **Infographic – Bionic Man and Sophia**)

17.15 BIOROBOTICS

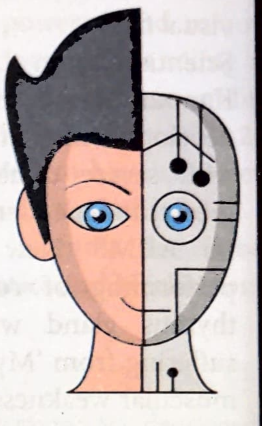
With an understanding of biomechanics, engineers can develop biologically inspired robots, with improved and enhanced capabilities over traditional robots, which are robotic! Biologically inspired robots have greater mobility and flexibility than traditional robots and often possess sensory abilities.

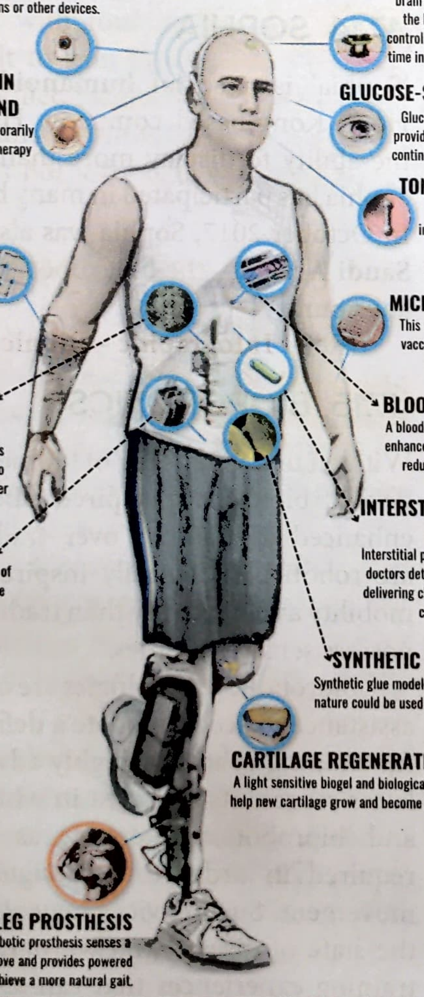
Biorobotic technologies are often utilised to provide assistance to accommodate a deficiency – either as fully functioning robots or highly advanced prosthetics; the latter represents one area in which neural engineering and biorobotics intersect, as both disciplines are required in order to first signal and then generate movement. Such devices may also be used to measure the state of disease, track progress or offer interactive training experiences that can speed recovery from an injury or stroke.

BIONIC MAN

- In robotics, the term "Bionic Man" refers to the development of robotic systems that mimic or enhance human capabilities. This includes bionic limbs, which replicate natural limb functions to restore mobility for amputees and individuals with limb impairments. Advanced bionic limbs can be controlled using neural interfaces, allowing users to command them with their thoughts.
- Researchers are also exploring the creation of full-body exoskeletons, wearable robotic suits that augment strength and endurance. These exoskeletons find applications in healthcare, manufacturing, and military sectors.
- Furthermore, there are ongoing advancements in humanoid robot development, aiming to create robots with human-like capabilities that interact with humans, perform tasks in human environments, and assist in various applications like healthcare and customer service. It's important to note that while these advancements bring us closer to the idea of a bionic man with enhanced abilities, current robotics and bionics primarily focus on practical assistive technologies and specialized applications, rather than creating superhuman capabilities.
- Rex Bionics Limited is a notable company specializing in robotic exoskeletons called Rex. Their advanced technology enables independent mobility for wheelchair users and individuals with mobility impairments. Rex was first conceptualized in 2003, with the first prototype completed in 2007. It was launched in 2010 and made commercially available for purchase in 2011.
- In the 1970s, the term "Bionic Man" gained popularity through the TV show "The Six Million Dollar Man," featuring a former astronaut named Steve Austin whose body was rebuilt with artificial parts. Today, engineers have created a robot resembling the concept of a true Bionic Man, with artificial organs, limbs, and other body parts.
- This fully bionic creation can walk, talk, and possesses a functioning artificial heart. It includes artificial organs such as lungs, pancreas, spleen, kidney, and a functional circulatory system. Its prosthetic limbs incorporate a state-of-the-art heart-lung system, modified-polymer arteries with artificial blood, a bionic spleen for blood cleansing, an artificial pancreas for blood sugar regulation, and retinal implants for vision.

  Additionally, the Bionic Man incorporates artificial intelligence, enabling it to listen and respond to speech through cochlear implants and a speech generator.





WIRELESS BRAIN-COMPUTER INTERFACE
The wireless brain-computer interface records and transmits brain activity wirelessly and could allow people with paralysis to use their thoughts to control robotic arms or other devices.

OPENING THE BLOOD BRAIN BARRIER WITH ULTRASOUND
Focused ultrasound could be used to temporarily open the blood brain barrier to let gene therapy treatments reach the brain.

IMPLANTABLE SENSORS FOR PROSTHESIS CONTROL
Implantable sensors detect nerve signals above a missing limb and can use these signals to move a prosthesis in a more natural way.

SPINAL STIMULATION FOR PARALYSIS
Electrical stimulation of the spinal cord is being used in individuals with paralysis to help restore voluntary movement and other functions.

ARTIFICIAL KIDNEY
An artificial kidney could be used in place of kidney dialysis for treatment of end-stage kidney disease.

ROBOTIC LEG PROSTHESIS
This powered robotic prosthesis senses a person's next move and provides powered assistance to achieve a more natural gait.

FLEXIBLE ELECTRODES RECORD BRAIN ACTIVITY
Flexible electrode array records brain activity from the surface of the brain and could be used to control robotic arms or provide real-time information about brain states.

GLUCOSE-SENSING CONTACTS
Glucose-sensing contacts could provide a non-invasive solution for continuous blood sugar monitoring.

TONGUE DRIVE SYSTEM
Tongue Drive System helps individuals with severe paralysis navigate their environment using only tongue movements.

MICRONEEDLE PATCH
This microneedle patch delivers vaccines painlessly and doesn't require refrigeration.

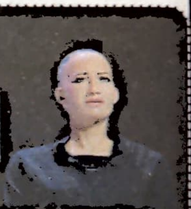
BLOOD CLOT EMULATOR
A blood clot emulator can be used to enhance ventricular assist devices to reduce the risk of blood clots.

INTERSTITIAL PRESSURE SENSOR
Interstitial pressure sensor could help doctors determine optimal times for delivering chemotherapy/radiation to cancer patients.

SYNTHETIC TISSUE ADHESIVE
Synthetic glue modeled after an adhesive found in nature could be used to repair tissues in the body.

CARTILAGE REGENERATION
A light sensitive biogel and biological adhesive help new cartilage grow and become functional.

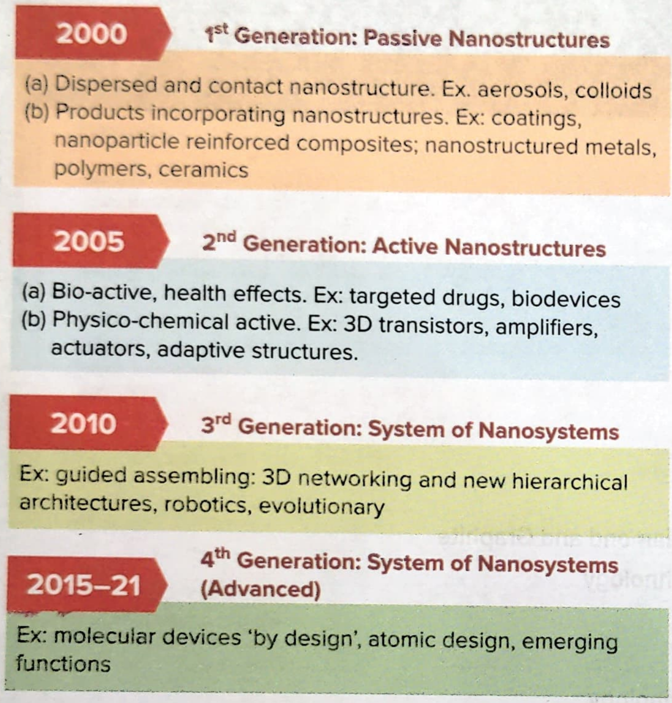
SOPHIA



- 'Sophia' is a social humanoid robot developed by Hong Kong-based company, Hanson Robotics. With the ability to display more than 62 facial expressions, Sophia has participated in many high-profile interviews. In October 2017, Sophia was also given citizenship of Saudi Arabia – the first robot to receive citizenship of any country.
- The robot is modelled after actress 'Audrey Hepburn' and uses artificial intelligence, visual data processing and facial recognition. Cameras within Sophia's eyes combined with computer algorithms allow her to see. She can follow faces, maintain eye contact and recognize individuals. She can process speech and can have conversations using Alphabet's Google Chrome voice recognition technology and other tools.
- Sophia also imitates human gestures and facial expressions and can answer certain questions and can make simple conversations on predefined topics (e.g., on the weather).
- Hanson designed Sophia to be a suitable companion for the elderly at nursing homes, or to help crowds at large events or parks. Sophia has nine robot humanoid 'siblings' who were also created by Hanson Robotics – Alice, Albert Einstein Hubo, Bina-48, Han, Jules, Professor Einstein, Philip K. Dick Android, Zeno and Joey Chaotic. Sophia would ultimately be a good fit to serve in healthcare, customer service, therapy and education.
- After making the news of having acquiring citizenship, Sophia made her first trip to INDIA (land of diverse and rich culture). She made appearances at IIT-B and WCIT (World Congress on Information Technology) held at Hyderabad. The entire conversation in IIT-B fest was based on problems in different parts of the world, to how robots can bring evolution in human world. Apart from this, she made her stand on women and her status around the globe. Here, she made it with her witty replies to the questions asked by the audience and showed the capabilities of humans embarking on a journey of AI.
- This development has made way for bright future of AI era, which has arrived. Development of robots in future can serve a huge purpose.

18.1 NANO AND TECHNOLOGY

The term 'Nanotechnology' came from nanometre, which is a length unit in the metric system, equivalent to one billionth of a metre (10^{-9}). It is the manipulating study matter on an atomic scale. Nanotechnology's periodical development is summarised in **Figure 18.1**.


2000 1st Generation: Passive Nanostructures

(a) Dispersed and contact nanostructure. Ex. aerosols, colloids
(b) Products incorporating nanostructures. Ex: coatings, nanoparticle reinforced composites; nanostructured metals, polymers, ceramics

2005 2nd Generation: Active Nanostructures

(a) Bio-active, health effects. Ex: targeted drugs, biodevices
(b) Physico-chemical active. Ex: 3D transistors, amplifiers, actuators, adaptive structures.

2010 3rd Generation: System of Nanosystems

Ex: guided assembling: 3D networking and new hierarchical architectures, robotics, evolutionary

2015–21 4th Generation: System of Nanosystems (Advanced)

Ex: molecular devices 'by design', atomic design, emerging functions

Figure 18.1
Timeline of Nanotechnology

18.2 HISTORY

- In the year 1959, the first theory on Nanotechnology was developed by the famous physics professor, **Dr. Richard P. Feynman.**
- In 1981, Eric Drexler published the first technical paper on 'Molecular Nanotechnology'. After that, in 1985, Richard Smalley and Robert Curl, with astronomer Sir Harry Kroto, discovered a new form of carbon (3-1) nanoscale carbon cages.
- The **scanning tunnelling microscope invention** in 1981 and the **fullerene discovery** in 1985 led to the emergence of nanotechnology. Fullerene is a C60 Carbon made compound.
- Dr. Nori Taniguchi, a Japanese scientist coined the term "nanotechnology" in 1974.
- **In 1996, the Nobel Prize in Chemistry was awarded jointly to Sir Harold W. Kroto, Richard E. Smalley and Robert F. Curl, 'for their pioneer discovery of fullerenes'.**
- **Fullerence:** A fullerene is a molecule of sixty carbons in the form of a hollow sphere, ellipsoid, tube and in many other shapes. Spherical fullerenes are also called buckyballs and cylindrical structures are called Bucky tubes or carbon nanotubes (**Figure 18.2**).

Different number of carbon and shape form different types of substances in nanotechnology – 0-dimensional Structure is Buckyball (Synthetic),

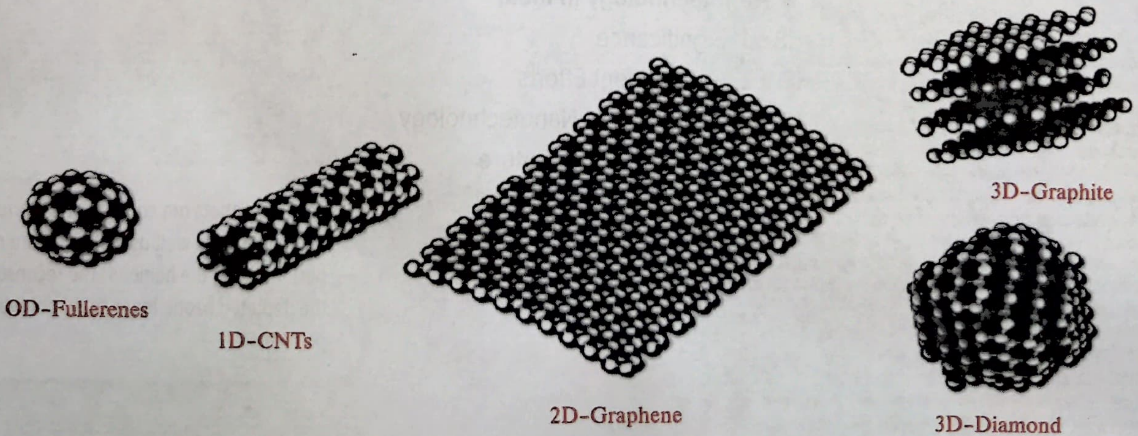


Figure 18.2
Evolution of different dimensional structures of Nanotechnology

1-dimensional Structure is Carbon Nanotubes (Synthetic), 2-dimensional structure is Graphene (Synthetic) and in 3-dimensional structure has Graphite (natural and synthetic both), which is an allotrope of diamonds (natural).

Note: If a chemical element or compound exists in two or more than two different forms, all are called allotropes, and this type of behaviour is called allotropy.

18.3 FULLERENES

The Buckminsterfullerene was the first fullerene to be discovered. It was named after the American architect, Buckminster Fuller, as it has resemblance to the geodesic dome designed by him. The Buckminsterfullerene is an allotrope of carbon. Due to its relative ease of synthesis, fullerene of C60 remains popular and a lot of research for its potential applications has been carried out. The C60 buckyball is made of 60 carbons at 60 vertices that makes a spherical structure.

These molecules have very high tensile strength and bounce back to their original shape. Due to the unique properties of this allotrope of carbon, it has a number of applications – a few of them have been discussed below:

.4 CARBON NANOTUBE

Carbon is the only element in nature found with varying physical and chemical characteristics. In 1991, Sumio Iijima discovered a new form of pure carbon with few nanoscopic threads. He found closed graphite structures including nanoparticles and became known as 'NanoTubes'. The world's tiniest carbon nanotube that has been produced is 0.4 nm wide in NEC Japan. Carbon nanotubes are exceptionally strong against any crack or damage. As the nanotubes are hollow, tubular and caged molecules, they are ideal for gas and lithium storage for drag delivery. It has vast amount of capacity to conduct electricity and heat than diamond. In India, scientists started research on carbon nanotubes in the early 1990s.

Properties

- Generally, the ratio of length-to-diameter of carbon nanotubes is up to 132,000,000:1.
- These are the fullerene structural family members. One atom-thick sheets of carbon with their long, hollow structure derives carbon nanotube. Carbon nanotube is a one-dimensional structure of carbons.
- They posses the highest strength-to-weight ratio, and assists in creation of *lightweight spacecraft.*
- It can easily penetrate through membrane so it will be helpful in *cancer treatment.*

18.5 GRAPHENE

It is defined as a one-atom thick layer. It is a two-dimensional network of carbon atoms and is the fundamental element of different allotropes such as charcoal, graphite, fullerenes and carbon nanotubes. It is the one of the strongest and thinnest materials known. Nobel Prize in Physics 2010 has been awarded to Andre Geim and Konstantin Novoselov "for ground-breaking experiments regarding the **two-dimensional material graphene**".

(Refer **Infographic – Nanotechnology**)

18.6 COMPARISON BETWEEN DIAMOND AND GRAPHITE

Diamond	Graphite
It occurs naturally in free state.	It occurs naturally and is manufactured artificially also.
It is the hardest natural substance known.	It is soft and greasy to touch.
It has high relative density (about 3.5).	Its relative density is 2.3.
It is transparent and has high refractive index (2.45).	It is black in colour and opaque.
It is non-conductor of heat and electricity.	It is a good conductor of heat and electricity.
It burns in air at 900° C to give CO_2.	It burns in air at 700–800° C to give CO_2.
It occurs as octahedral crystals.	It occurs as hexagonal crystals.
It is insoluble in all solvents.	It is insoluble in all ordinary solvents.

Nanomaterials and Quantum Dots (Nano Rods)

Nanomaterials include many materials: nanoparticles, nanowires, nanoporous solids, nanocapsules and DNA chips. Many molecular structures have been developed at the nanoscales for making them functional in various applications. Examples: Nanocrystals (1–10 nm), Quantum dots (1–100 nm), Nanowires (1–100 nm), Nanoporous solids (0.5–10 nm), 2-D arrays [several nm^2- um^2 (micrometre)], 3-D structures (several nm) and Surface thin films (1–1000 nm).

NANOTECHNOLOGY

What is Nano Technology?

- Nanotechnology is a field of science and technology that focuses on the manipulation and control of matter at the nanoscale, which is the scale of individual atoms and molecules.
- It involves the understanding, characterization, and utilization of materials and systems with unique properties and behaviors at the nanoscale.
- The prefix "nano" refers to one billionth of a meter (10^-9 meters), which is about the size of individual atoms or small molecules. At this scale, the properties of materials can differ significantly from their bulk counterparts.
- Nanotechnology aims to exploit these unique properties by designing, manipulating, and engineering materials and devices at the atomic and molecular levels.

Applications of Nano Technology

Electronics and Computing

Nanotechnology has revolutionized the electronics industry by enabling the development of smaller, faster, and more efficient devices. It has led to the miniaturization of computer chips, increased storage capacity of memory devices, and enhanced performance of electronic components.

Medicine and Healthcare

Nanotechnology has made significant contributions to medicine and healthcare. It has enabled the development of targeted drug delivery systems, where nanoparticles are used to deliver medications directly to specific cells or tissues, reducing side effects and improving efficacy. Nanomaterials are also used in medical imaging, biosensors for diagnostics, tissue engineering, and regenerative medicine.

Energy

Nanotechnology has the potential to address energy challenges by improving energy generation, storage, and efficiency. For example, nanomaterials are being explored for the development of more efficient solar cells, advanced batteries, and fuel cells. Nanotechnology also plays a role in energy conservation by improving the insulation properties of materials and developing energy-efficient coatings.

Environmental Remediation

Nanotechnology offers solutions for environmental remediation and pollution control. Nanomaterials can be used for water purification, air filtration, and remediation of contaminated soil and groundwater. They enable enhanced adsorption, filtration, and degradation of pollutants.

Agriculture and Food Industry

Nanotechnology can contribute to improving agricultural practices and food production. Nanosensors can monitor soil quality, detect pests and diseases, and optimize crop growth. Nanomaterials can be used for targeted delivery of nutrients and pesticides, extending the shelf life of perishable foods, and developing smart packaging to prevent spoilage.

Materials Science and Engineering

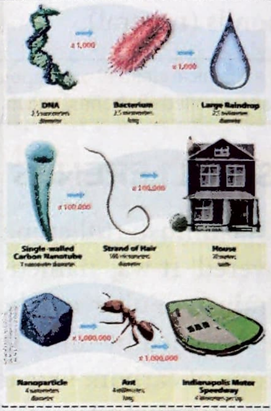
Nanotechnology has opened up new possibilities in materials science and engineering. Nanomaterials exhibit unique properties, such as increased strength, enhanced conductivity, improved optical properties, and higher chemical reactivity. These materials find applications in areas such as lightweight and high-strength composites, flexible electronics, catalysis, and coatings with special functionalities.

Water Treatment and Desalination

Nanotechnology plays a role in water treatment and desalination processes. Nanomaterials, such as nanoparticles and nanofilters, can effectively remove contaminants, bacteria, and viruses from water sources. Additionally, nanomembranes are being explored for efficient desalination, enabling the production of fresh water from seawater.

What is Nano Scale

- The nanoscale refers to a length scale of nanometers (one billionth of a meter), where matter exhibits unique properties.
- At this scale, quantum effects become prominent, and the surface area-to-volume ratio increases significantly.
- Nanotechnology focuses on working with materials and structures at the nanoscale to manipulate their properties.
- Scientists and engineers can design and engineer nanomaterials by controlling their size, shape, composition, and surface properties. Nanotechnology enables the development of novel applications and technologies in various fields.



Environmental Impacts of Nano Technology

Exposure and Toxicity

The small size and unique properties of nanomaterials can lead to increased reactivity and potential toxicity. Studies have shown that certain nanoparticles may have adverse effects on organisms and ecosystems, including cellular damage, inflammation, and environmental disruption. It is crucial to understand the potential risks and conduct comprehensive assessments of nanomaterials before their widespread use.

Environmental Fate and Behavior

Nanomaterials released into the environment may behave differently compared to their bulk counterparts. They can disperse more widely, travel longer distances, and potentially accumulate in ecosystems. It is necessary to study the fate, transport, and transformations of nanomaterials in different environmental compartments to evaluate their potential long-term effects.

Ecotoxicity and Ecosystem Impact

Engineered nanomaterials may interact with organisms and ecosystems, leading to ecological effects. They can enter aquatic systems, soil, and the atmosphere, potentially affecting various organisms across different trophic levels. Understanding the potential ecotoxicity and ecosystem impacts of nanomaterials is critical to mitigate their adverse effects.

Life Cycle Assessment

Assessing the environmental impact of nanotechnology requires considering the entire life cycle of nanomaterials and nanotechnology-enabled products. This includes evaluating the environmental footprint associated with the production, use, and disposal of nanomaterials, as well as the potential for resource depletion, energy consumption, and waste generation.

Regulatory Framework

To ensure the responsible development and use of nanotechnology, regulatory frameworks need to be established or strengthened. Governments and international organizations are actively working to develop guidelines and regulations that address the potential environmental and health risks associated with nanomaterials.

Sustainable Nanotechnology

The concept of sustainable nanotechnology promotes the responsible design, production, and use of nanomaterials and nanotechnology-enabled products. This approach emphasizes minimizing environmental impacts, reducing toxicity, conserving resources, and promoting the safe and ethical use of nanotechnology.

What is Carbon Fibre?

- Carbon fiber, also known as carbon fibre, is a lightweight and high-strength material composed of carbon atoms arranged in a crystalline structure.
- It is a type of fiber-reinforced polymer (FRP) where the reinforcing material is carbon fiber.
- The production of carbon fiber involves several steps. It begins with the precursor material, usually a polymer, such as polyacrylonitrile (PAN), rayon, or pitch. The precursor undergoes a series of treatments, including oxidation and carbonization, to remove non-carbon elements and convert the material into pure carbon fibers.
- Characteristics and Applications of Carbon Fibers
  - Physical strength, specific toughness, light weight Aerospace, road and marine transport, sporting goods
  - High dimensional stability, low coefficient of thermal expansion, and low abrasion Missiles, aircraft brakes, aerospace antenna and support structure, large telescopes, optical benches, waveguides for stable high-frequency (GHz) precision measurement frames
  - Good vibration damping, strength, and toughness Audio equipment, loudspeakers for Hi-fi equipment, pickup arms, robot arms
  - Electrical conductivity Automobile hoods, novel tooling, casings and bases for electronic equipments, EMI and RF shielding, brushes
  - Biological inertness and x-ray permeability Medical applications in prostheses, surgery and x-ray equipment, implants, tendon/ligament repair
  - Fatigue resistance, self-lubrication, high damping Textile machinery, genera engineering
  - Chemical inertness, high corrosion resistance Chemical industry; nuclear field; valves, seals, and pump components in process plants
  - Electromagnetic properties Large generator retaining rings, radiological equipment

Applications of Carbon Fibres

- Aerospace and Aviation: Carbon fiber composites are extensively used in the aerospace industry to reduce weight while maintaining structural strength.
- Automotive: Carbon fiber is used in high-performance vehicles to reduce weight and improve fuel efficiency.
- Sports and Recreation: Carbon fiber is widely used in sporting goods and equipment, such as tennis rackets, golf clubs, bicycle frames, and helmets. Its high strength and lightweight properties enhance performance and durability.
- Wind Energy: Carbon fiber composites are used in wind turbine blades to provide strength and flexibility while minimizing weight.
- Civil Engineering and Construction: Carbon fiber is employed in structural reinforcements, such as beams, columns, and bridge decks, to enhance strength and durability. It is also used in seismic retrofitting to reinforce buildings against earthquakes.

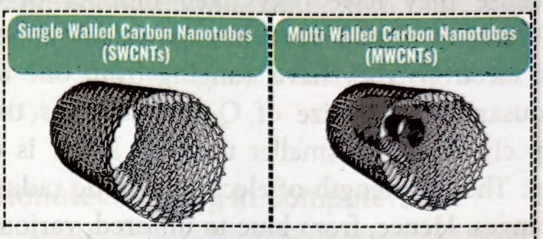
Carbon Nano Tubes

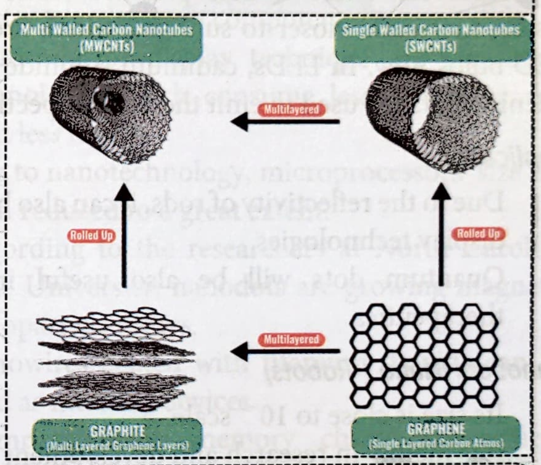
- Carbon nanotubes (CNTs) are cylindrical structures made up of carbon atoms arranged in a tube-like fashion.
- They have a nanoscale diameter, typically on the order of a few nanometers, and can have lengths ranging from a few micrometers to several centimeters.
- Carbon nanotubes can be categorized into two main types:
  a. Single-walled carbon nanotubes (SWCNTs): These nanotubes consist of a single cylindrical layer of carbon atoms. They have a hollow core and can be thought of as rolled-up sheets of graphene. SWCNTs exhibit exceptional electrical conductivity and mechanical strength. They possess unique properties that can vary depending on their diameter, chirality (twist), and structure.
  b. Multi-walled carbon nanotubes (MWCNTs): These nanotubes consist of multiple concentric layers of carbon atoms. MWCNTs can be envisioned as multiple SWCNTs nested within one another, forming a tube within a tube structure. MWCNTs offer enhanced mechanical properties and improved resistance to structural defects compared to SWCNTs
- Carbon nanotubes possess numerous extraordinary properties, including:
  - Exceptional strength: They have one of the highest strength-to-weight ratios of any known material, making them incredibly strong and lightweight.
  - High electrical conductivity: Carbon nanotubes can conduct electricity with high efficiency due to their unique electronic properties, making them useful in electronics and nanoelectronics applications.
  - Thermal conductivity: They exhibit high thermal conductivity, making them valuable for heat management applications.
  - Structural flexibility: Carbon nanotubes can be bent and twisted without breaking, allowing for their integration into various structures and devices.
  - Potential for nanoscale applications: Their small size and unique properties make them promising candidates for nanoscale devices, sensors, and other applications.
- However, there are still challenges to overcome in terms of large-scale production, cost-effectiveness, and addressing any potential health and environmental concerns associated with their usage. Ongoing research continues to explore and unlock the full potential of carbon nanotubes for practical applications.
- Applications of CNT
  - Some industries like Easton-Bell Sports, Inc. make use of CNT in manufacturing the components of bicycles.
  - By the use of CNT, Zyvex Technologies manufactures lightweight boats.
  - It will replace silicon-made transistors, as they are small and emit very less heat.
  - In electric cables and wires, it will conserve electricity against losses.
  - Tiny size CNT made transistors will have a lot of advancement in communication and information technology.
  - In photovoltaics, it can be used as solar cells.
  - In fabrics, small-sized CNT can be used.

Recently, it has been demonstrated that functionalized carbon nanotubes can be degraded by oxidative enzymes. This finding is offering a new perspective for the development of carbon nanotubes in medicine. Enabling technology would facilitate the making of nanodevices using these blood-compatible nanomaterials as building blocks for biomedical applications such as artificial implants, including structural tissue replacements, that is, artificial blood vessels or functional devices such as drug delivery matrices.

Biochemical Sensors Using Carbon Nanotube Arrays.

NASA has successfully demonstrated a miniaturized electronics technology with extremely high sensitivity and simplified sample preparation for in vitro detecting specific biomarker signatures, which is based on incorporating embedded vertically aligned carbon nanotubes as nanoelectrode arrays in diagnostics devices.


Single Walled Carbon Nanotubes (SWCNTs)
Multi Walled Carbon Nanotubes (MWCNTs)


Multi Walled Carbon Nanotubes (MWCNTs)
Single Walled Carbon Nanotubes (SWCNTs)
Multilayered
Rolled Up
Rolled Up
Multilayered
GRAPHITE (Multi Layered Graphene Layers)
GRAPHENE (Single Layered Carbon Atoms)

Graphene

- Graphene is a two-dimensional sheet of carbon atoms arranged in a hexagonal lattice pattern. It is a single layer of graphite, which is the material commonly found in pencil lead. Graphene is the thinnest, strongest, and most conductive material known to exist.
- Key properties of graphene include:
  - Strength and Flexibility: Graphene is incredibly strong yet highly flexible, capable of stretching and bending without breaking.
  - Electrical Conductivity: Graphene has exceptional electrical conductivity, making it suitable for various electronic applications.
  - Thermal Conductivity: Graphene possesses excellent thermal conductivity, efficiently transferring and dissipating heat.
  - Transparency: Graphene is highly transparent, allowing over 97% of light to pass through.
  - High Surface Area: Graphene has a large surface area relative to its weight, making it useful for energy storage and catalysis.

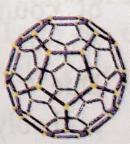
Graphene Layer

Applications of Graphene

- From 2014 onwards, usage of graphene is being undertaken for commercial purposes and various applications are proposed or actively under development, in various areas such as filtration, lightweight/strong composite materials, electronics, photovoltaics, energy storage and biological engineering.
  - Biomedical: Graphene can be used for DNA analysis and applications in genetics and biotechnology.
  - Integrated Circuit: Graphene's properties enable high-speed transistors for processors and integrated circuits.
  - Optical Electronics: Graphene's electrical conductivity and optical transparency find use in touchscreens, displays, and photovoltaic cells.
  - Filters and Desalination: Graphene oxide filters show potential for water desalination.
  - Ethanol Distillation: Graphene oxide membranes can selectively allow water vapor passage, aiding in biofuel and alcohol production.
  - Solar Cells: Graphene is applicable in photoelectrochemical energy conversion for efficient solar cells.
  - Energy Storage Devices: Graphene has potential for high-density supercapacitors, improving energy storage capacity.
  - Anti-bacterial: Graphene oxide demonstrates antimicrobial properties, offering benefits in hygiene and packaging.

Fullerene

- Fullerenes are a class of carbon molecules that consist of carbon atoms arranged in closed cage or ball-like structures. The most well-known and studied fullerene is C60, also known as buckminsterfullerene or simply buckyball, which has a spherical shape resembling a soccer ball.
- Fullerenes were first discovered in 1985 and were named after Buckminster Fuller, an architect known for designing geodesic domes that share a similar structural pattern. They are composed entirely of carbon atoms, arranged in a pattern of hexagons and pentagons, similar to the pattern on a soccer ball. This unique arrangement gives fullerenes their distinctive properties.



Fullerene (C_{60} Molecule)

- Fullerenes exhibit interesting properties such as high tensile strength, excellent electrical conductivity, and high chemical stability. They are also known for their ability to form stable compounds with other molecules, making them versatile for various applications.
- Fullerenes have found applications in fields such as materials science, electronics, medicine, and energy. They can be used as catalysts, drug delivery vehicles, superconductors, and in solar cells, among other things. Their unique structure and properties make them a subject of ongoing research and exploration in nanotechnology and related fields.

Applications of Fullerene

- Antioxidants: They act as efficient radical scavengers.
- Cytoprotectors: They protect cells from ultraviolet damage.
- Cosmetics: Water-soluble derivatives prevent skin damage and aging.
- Antiviral Agents: They show activity against viruses like HIV and hepatitis C.
- Drug and Gene Delivery: They can transport drugs and DNA sequences to target cells.
- Photodynamic Therapy: They are used to target and treat malignant cells.
- Solar Cells: They enhance energy conversion in organic solar cells.
- Protective Eyewear: They can be used in optical limiters for eye protection.
- Hydrogen Storage: Fullerenes have potential for storing and releasing hydrogen.
- Hardening Agents: They strengthen lightweight metals without compromising ductility.
- Diamond Films: Fullerenes can be converted into diamond films for electronic applications.
- Fullerenes offer diverse possibilities in medicine, but further research is needed for practical implementation.

Quantum dots or nanocrystals are less than 10 nm and known as nanoscale particles. They are fabricated with the help of metals or semiconducting materials. Quantum dots can be considered as artificial atoms because they have only fixed number of electrons confined to a small area. They are roughly spherical and the electrons they have, ranging from one to several thousand. If the size of Q-dots changes then band gap changes. The smaller the size, larger is the band gap. The wavelength of electromagnetic radiation also changes. Hence, from blue to infrared, various Q-dots are observed. These Q-dots produce white light in visible spectrum, closer to sunlight, which are used in LED bulbs now. In LEDs, cadmium sulphide and zinc selenide dots are used to emit the visible spectrum.

Applications

- Due to the reflectivity of rods, it can also be used in display technologies.
- Quantum dots will be also useful in cancer therapeutics.

Nanobots (Nano + Robots)

- Its size is close to 10^{-9} scale.
- It is mainly in research and development phase.
- 1.5 nanometre-sized nanobots have the capability of counting specific molecules in a chemical sample.
- Due to microscopic size of nanobots, it would probably be necessary for very large numbers of them to work together to perform microscopic and macroscopic tasks.

Applications

- It will be useful for detection of toxic components in environment.
- In drug delivery system.
- In biomedical instrumentation and utilisation.

18.7 APPROACHES IN NANOTECHNOLOGY

18.7.1 Bottom Up

In this approach, the manufacturing of different materials and products is done from their own molecular components. They accumulate themselves in a chemical manner through their own breed recognition. The bottom-up approach calls for assembly of nanostructures from atoms and molecules. Self-assembly of nanotubes has been found to be a useful feature.

18.7.2 Top Down

In this approach, the nanomaterials and objects are produced by bigger bodies without its atomic reactions bouncing. Generally, there is more usage of the bottom-up than the top-down approach. The top-down approach refers to the building of nanostructures of progressively smaller and smaller dimensions using larger parts. DNA technology utilises the specificity Watson–Crick base preparing to construct well-defined structures out of DNA.

18.8 APPLICATION OF NANOTECHNOLOGY

18.8.1 Nanotechnology in Drugs (Cancer)

- It provides innovative methods for drug delivery and therapies.
- It assists in the accurate delivery of drugs in the body to the right location and further for controlling the infection; the drug doses are released on a fixed schedule for treatment.
- The drug will be delivered through a nano-sized carrier for becoming concentrated at the site of disease, i.e., cancer tumour. At the final destination, at a specific location, they release the medicine and kill the tumour cells in human body. This type of treatment is popular for drug targeting. Recent treatment is given through radiotherapy or chemotherapy, which not only kills cancerous cells but also kills normal cells that are necessary to the human life.
- Nanobots can clear the blockage in arteries and solve heart attack risk in human body.
- Nano-optics could allow for an increase in precision of pupil repair and other type of laser eye surgery.

18.8.2 Nanotechnology in Fabrics

- Some cloth producers are developing clothing which can strain and be water-repellent, through the usage of nano-sized whiskers in the fabric, thereby, causing water to drop from the cloths' surface.

- These fabrics can also be used in manufacturing bulletproof jackets.
- It makes spill and dirt-resistant clothes and also develops antimicrobial and antibacterial fabrics.

18.8.3 Nanotechnology in Mobile

- Nokia Research Centre (NRC) and the University of Cambridge (UK) combinedly developed **'Morph'**, a nanotechnology concept-based device. **Morph** is hydrophobic and dirt repellent in nature. It also has the capability to charge itself with accessible light sources due to the covering of photovoltaic nanowire on its surface.
- Nanoscale electronics technology also allows to stretch the handset. These nanoscale fibre mesh allows our mobile handsets to change into different shapes such as stretched, bent and folded into any number of imaginable shapes.

.4 Nanotechnology in Electronics

- The electrodes made up of nanowires assist the flat panel displays to be flexible as well as skinny.
- Chip fabrication can be done by Nanolithography (this technology involves fabricating nanoscale structures).
- The transistors are made up of nanowires, which brought revolution in communication and information technology.
- Nanotechnology helps in the manufacturing of e-paper, displays on sunglasses, etc.
- Recently available solar cells have much lower efficiencies (15–20%). Nanotechnology could help increasing this efficiency up to 40%.
- Nanobatteries are rechargeable batteries and the nanomaterials used here could be helpful for the battery disposal.

18.8.5 Nanotechnology in Computers

- Transistors based on carbon nanotubes can replace silicon transistors in computers.
- Nanorods for display technique are the future technology, which consume less electricity and emit less heat.
- Due to nanotechnology, microprocessors' size has been reduced to a great extent.
- According to the researchers at North Carolina State University, nanodots are growing magnetic nanoparticle arrays.
- Nanowires coated with titanium dioxide can be used as memory devices.
- Memristor-made memory chips can achieve higher memory density due to their small size.
- Before 'i' series processors, intel used chips of size ranging between 65 nm and 45 nm. Later on, due to nanotechnolgy, the size of chip reduced to 22 nm, which itself is a milestone.

WORLD'S FIRST MOLECULAR ROBOT

Scientists from the University of Manchester have created the world's first 'molecular robot' – millionth of a millimetre in size. It can be used to build molecules and may help discover novel drugs.

1. The molecular robot is millionth of a millimetre in size.
2. It is made up of just 150 carbon, hydrogen, oxygen and nitrogen atoms, which are basic building blocks required to form molecules.
3. It can be programmed to move and build molecular cargo using a tiny robotic arm.
4. The molecular robot operates by carrying out chemical reactions in special solutions, which can then be controlled and programmed by scientists to perform the basic tasks.
5. It responds to a series of simple commands that are programmed with chemical inputs.

Significance

The molecular robot is so small, that it massively reduces the demand for materials, dramatically reduces the power requirements, can accelerate and improve drug discovery and rapidly increases the miniaturisation of other products. Such molecular robots can be used for medical purposes, advanced manufacturing processes and even building molecular factories and assembly lines.

18.8.6 Other Uses

- As cutting tools, nanocrystalline materials, such as tungsten carbide, tantalum carbide and titanium carbide, are more wear and erosion-resistant and have good life than other conventional counterparts.
- Silver nanocrystal materials kill bacteria and prevent infection.
- Synthetic bone has been developed by the molecular level manipulation of calcium and phosphate through the nanoparticulate.
- The usage of lightest identified solid material, termed as 'Aerogels' in space suits and further proposed its usage in spacecraft due to good insulating properties are also importance of nanotechnology.

18.9 NANOTECHNOLOGY IN INDIA

Today, nanotechnology has great relevance, as it has the potential to address the needs of all innovative technological solutions.

18.9.1 Significance

The Indian government is looking towards nanotechnology as a means of accelerating agricultural productivity in the country. According to the Planning Commission, nanotechnologies such as nanosensors and nano-based smart delivery systems could help ensure natural resources like water, nutrients and chemicals; those are used efficiently in the field of agriculture. Nowadays, nanobarcodes and nano-processing could also be used to help in monitoring the quality of agricultural products.

Nanotechnology can help India in ensuring food security with increasing crop yields and reducing consumption. Nanotechnology can be used to supply water and nutrients to crops, thereby increasing the yield and reducing wastage. It can be used in preventing damage to stored food grains.

Nanotechnology can be used in public health, in India, with better medical practices and affordability. With the advancement of nanomedicine, researchers had developed nanobioceramics that repair bones and tissues and an aerosol spray that uses nanoparticles to deliver lung cancer drugs. A nano-based water filter and the 'Sens' (a sensor) are also developed in India as an affordable and user-friendly nanodiagnostic tool that anticipates heart attacks. It is expected to become commercially available soon. With its vast scientific and industrial base, India can become a leader in nanoscience and nanotechnology research.

18.9.2 Government Efforts

Nanotechnology is a knowledge-intensive and 'enabling technology' that can influence a wide range of products and processes with far-reaching implications for national economy and development. The government has been taking various initiatives to promote nanotechnology. Some of the prominent initiatives are:

1. **Nano Science and Technology Initiative (NSTI):** The Department of Science and Technology, in October 2001, had launched a modest programme in Nano Science and Technology, called the Nano Science and Technology Initiative (NSTI). Under the NSTI, the DST supported a number of activities in Nano Science and Technology. Based on the success of the NSTI, the second phase of DST's efforts was launched as the Nano Mission.
2. **Nano Mission:** The Government of India in May 2007 has approved the launch of a Mission on Nano Science and Technology (Nano Mission). The Department of Science and Technology (DST) is the nodal agency for the implementation of Nano Mission in India. An allocation of ₹1000 crore for 5 years has been made by DST for this research work. Two advisory groups guide the technical programmes of the Nano Mission:
   - (NSAG): Nano Science Advisory Group
   - (NATAG): Nano Applications and Technology Advisory Group

   Outcomes and Significance of the Mission
   - As a result of the efforts led by the Nano Mission, today, ***India is amongst the top five nations in the world, in terms of scientific publications in nanoscience and technology (moving from 4th to the 3rd position).***
   - The Nano Mission itself has resulted in about 5000 research papers and about 900 PhDs and also ***some useful products like nano hydrogel based eye drops, pesticide removal technology for drinking water, water filters for arsenic and fluoride removal, nano-***

NANOPHARMACEUTICALS

They are a relatively new class of *therapeutic-containing nanomaterials* that often have unique 'nanoproperties' (physiochemical properties) due to their small size (compared with their bulk-phase counter parts), a high surface-to-volume ratio and the possibility of modulating their properties.

- *Nanopharmaceuticals present novel reformulation opportunities for active agents* (e.g., single molecule drugs, proteins, nucleic acids, etc.) that were previously insoluble or could not be targeted to a specific site of the body where they were needed.
- Nanopharmaceuticals can *also increase drug half-life* by reducing immunogenicity and diminishing drug metabolism.
- With these advantages, *nanopharmaceuticals have the ability to extend the economic life of proprietary drugs*, thereby creating additional revenue streams.

A Guideline was released for Evaluation of *Nanopharmaceuticals* in India. *Those are developed by* DBT, ICMR and Central Drugs Standard Control Organization (CDSCO). Developed *in line with the provisions of Schedule of Drugs and Cosmetics Rules, 1945 as well as Second Schedule of the New Drugs and Clinical Trials Rules, 2019* with specific requirements for nanopharmaceuticals.

Need for these guidelines

Nanocarrier-based targeted drug delivery is an emerging field with introduction of *nanopharmaceuticals* in the market. These nanoformulations have higher efficacy, lower toxicity and are safer than the conventional drugs. Therefore, to provide *transparent, consistent and predictable regulatory pathways for nanopharmaceuticals in India* these guidelines were necessary.

Application of these guidelines

The guidelines apply to the nanopharmaceuticals in the form of *finished formulation as well as Active Pharmaceutical Ingredient (API)* of a new molecule or an already approved molecule with altered nanoscale dimensions, properties or phenomenon associated with the application of nanotechnology intended to be used for treatment, in vivo diagnosis, mitigation, cure or prevention of diseases and disorders in humans.

Significance

- These guidelines mark one of the most important steps for delineating quality, safety and efficacy assessment of the novel nanoformulations.
- The guidelines will pave the way for significant benefits through such cutting edge technology and contribute to the mission on '*Affordable Health Care for All*.
- Private investments would also be attracted since *these guidelines would strengthen the regulatory system.*

silver-based antimicrobial textile coating, etc.

- The Nano Mission has thus helped establish a good ecosystem in the country to pursue front-ranking basic research and also to seed and nurture application-oriented R&D, focussed on useful technologies and products.
- **The International Conference on Nano Science and Nano Technology (ICONSAT)** under the aegis of **Nano Mission,** Department of Science and Technology (DST) was held at ***Kolkata*** (March 5–7, 2020) focussing on **the recent advances in this frontier research field.**

3. **Nanotechnology Initiatives Programme:** The Department of Information Technology (DIT) and Ministry of Communications and Information Technology (MCIT) has inaugurated the Nanotechnology Initiatives Programme in 2004. It is mainly concentrating on nanoelectronics aspects of the nanotechnology. The focus of the programme is on capacity building and human resource development, infrastructure creation and research and development in nanoelectronics, nanotechnology and nanometrology. This programme emphasises on the establishment of major centres on nanoelectronics and nanometrology in India. This programme brings a number of R&D projects at the academic level of R&D organisations across the country and also involves in Indian nanoelectronics user programmes.

MISSION ON NANO SCIENCE AND TECHNOLOGY (NANO MISSION)

- It was Launched in 2007.
- It is as an 'umbrella capacity-building programme'.
- The Mission's programmes will target all scientists, institutions and industry in the country.
- It will also strengthen activities in nanoscience and technology by promoting basic research, human resource development, research infrastructure development and international collaborations among others.
- It will be anchored in **the Department of Science and Technology** and steered by a **Nano Mission Council, chaired by an eminent scientist.**

4. **National Nanotechnology Institutes:** The government has identified three cities– Bengaluru, Mumbai and Kolkata – for the promotion and development of nanotechnology, by setting up the Indian Institute of Nano Sciences (IINS) at these three locations. The institutes will primarily focus on advanced scientific research in nanotechnology.
5. **Vision Group for developing a National Nanotechnology Policy:** India formed a Vision Group in January 2008, consisting of about a dozen researchers from academics, industries and research spheres to develop a National Nanotechnology Policy in India.
6. **Bengaluru Nano (Bengaluru India Nano Conference):** Bengaluru Nano is organised by the Government of Karnataka and the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bengaluru. It is a biannual event. The event comprises exhibition, of conference and provides a meeting place for global scientists, industry, academia and government.
7. **International Collaboration:** Besides launching the Nano Science and Technology Initiative and Nano Mission, India has also put its step into bilateral nanotechnology programmes with the European Union, Germany, Italy, Taiwan and the United States. India is a participant in the IBSA (India–Brazil–South Africa) nanotechnology initiative. It was started as a collaborative programme between the Department of Science and Technology of three participating countries, with a goal of developing trilateral collaborative projects of common relevance and interest.
8. **Nanotechnology Regulatory Board:** In February 2010, the Nano Mission Council stated that India will have a Nanotechnology Regulatory Board to regulate the industrial nanotech products that are used in day-to-day life. It is felt that India should have an efficient regulatory body and well-defined protocols for dealing with the deployment of nanotechnology like handling, movement and approval of nanoproducts and also to maintain an adequate database on its toxicity.

18.9.3 Objectives of Nanotechnology

- Promotion of basic research in nanotechnology.
- To provide infrastructure for Nanoscience and technology research.
- To enhance Nanoapplications and technology through promotion of application-oriented research and development projects with special efforts, either directly through industrial sector into nanotechnology research and development or through Public Private Partnership (PPP) ventures.
- Human Resource Development – Nano Mission should focus on providing effective education and training to researchers and professionals in diversified fields those enhance Interdisciplinary culture for nanoscale science, engineering and technology.
- International collaborations through exploratory visits of scientists and involvement in various workshops and conferences under various joint research projects.

18.10 POSSIBILITIES FOR THE FUTURE

- With the help of nanotechnology, there comes the possibility of manufacturing lighter, stronger and programmable materials, which require less energy than conventional material to generate and guarantee greater fuel efficiency in land, ships, aircrafts, transportation and space vehicles.

- Nanorobotics has a good future in medicine as a drug targeting and gene therapy.
- The nanorobots are capable of undertaking human tasks as well as tasks that are not being performed by the humans. The reconstruction of the depleted ozone layer could potentially be performed.
- Nanosurgical field helps in the treatment of everything from natural aging to diabetes, etc. Everything will be repaired easily with the introduction of nanosurgery.

18.11 PITFALLS OF NANOTECHNOLOGY

Nanoparticles can easily enter into the human body through food, skin or lungs and produce free radicals, thereby causing cell damage. If nanoparticles enter the bloodstream and cross the blood–brain barrier, they will become more dangerous to human life. Nano-bomb is the most dangerous outcome of the use of nanotechnology that contains engineered self-multiplying deadly viruses that are dangerous at different levels, like community, country or even an entire civilisation.

QUESTIONS AND ANSWERS

BJECTIVE QUESTIONS

nsider the following statements:

(i) Targeted drug delivery is made possible by

19.1 INTRODUCTION

Intellectual Property is a **collection of ideas and concepts,** which can be protected through trademarks, copyrights and patents. IPR, in literal sense, means something that emanates from human brain. **IPR are the rights which allow the patent holder, trademark carrier or copyrighted work to benefit them for their brainwork or investment.** These rights have been outlined under Article 27 of Universal Declaration of Human Rights (UDHR). The importance of IPR was first recognised in the Paris Convention for the Protection of Industrial Property (1883) and Berne Convention for the Protection of Liberty and Artistic Works (1886) (both administered by WIPO).

Intellectual property can be better understood with various types.

1.1 Copyrights

It is the exclusive rights bestowed or given upon the creator, writer, author, artist or any one of their original works to print, publish or record for a **fixed period of time.**

19.1.2 Trademarks

It is a distinguishable **symbol, signature** or **design** of goods or products or services **representing a particular company.** It deals with the reputation of the Company's brand, essentially acting as a guarantor or indication of the origin of the service or products provided. Example: Coca Cola.

19.1.3 Patents

Patents can be termed as **legal monopoly** granted to an individual or a firm to make use of their brainwork by others, which can be done by selling their invention and making it a restricted property for use. An invention can also be sometimes rendered as a solution to any specific technological problem that can be a product or a process.

There are three following conditions to recognise any invention:

(a) It has to be a new invention,
(b) It should not be obvious, and
(c) Their needs should hold industrial application.

19.1.4 Industrial Design

Industrial design trains one to blend art with applied science in order to improve a product in terms of **visual aspects,** its application and usage.

19.1.5 Trade Secrets

A trade secret is the protecting or concealing of certain **recipes, processes, formulae or designs, patterns, information of certain product** by a particular company or business firms, thereby giving themselves an edge and advantage over competitors.

19.1.6 Trade Dress

Trade dress, like Trademark, is a source identifier or indicator to the customers but the difference is that it is not only the symbol or short phrase of the company but everything that a company does to their product, **presenting itself to the customer distinctively, from giving visual appeal to a product or from packaging that signifies the source of the product to consumers.**

19.1.7 Plant Varieties

These are the rights given for the usage of a new plant species commercially, which is original and different and in order to get them registered, the variety's propagating material assessment is to be scrutinised.

19.1.8 Geographical Indications (GI TAG)

A geographical indication (GI) is a name or sign used on certain products which **correspond to a specific geographical location or origin (e.g., a town, region or country).**

India, as a member of ***the World Trade Organization (WTO), enacted the Geographical Indications of Goods (Registration and Protection) Act, 1999 which came into force with effect from 15 September 2003.***

GIs have been defined under Article 22(1) of the WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement as: 'Indications which identify a good as originating in the territory of a member, or a region or a locality in that territory, where a given quality, reputation or characteristic of the good is essentially attributable to its geographic origin'.

The GI tag ensures that none other than those registered as authorised users (or at least those residing inside the geographic territory) are allowed to use the popular product name. **Darjeeling tea became the first GI tagged product in India, in 2004-05.**

19.2 NEED FOR INTELLECTUAL PROPERTY RIGHTS

Intellectual Property Rights (IPR) are needed for the following reasons:

- They protect and safeguard the capacity of humans in their creation or creativity and their invention of new works in different fields or areas.
- They legally safeguard and protect new inventions and conceptions, thereby motivating the resources for more novelty.
- Protection of intellectual property **enhanced economic growth,** thereby creating new jobs and opportunities in industries. Efficient management of intellectual property rights can act as a driving force for economic, social and cultural well-being of the people.
- Intellectual Property (IP), in a way, **helps in maintaining a balance between the interests of creators and the public, providing** an environment for creativity and innovation to flourish.

[Refer **Infographic – Intellectual Property Rights (IPR)**]

KAPILA

- The Government has launched a campaign namely **Kalam Program for Intellectual Property Literacy and Awareness Campaign (KAPILA)** for Intellectual Property Literacy and creating patent awareness.
- The objectives of the scheme include creating awareness regarding IPR in Higher Education Institutions (HEIs), enabling IP protection of inventions originating from faculty and students of HEIs, development of Credit Courses on IPR, training programmes, etc.

19.3 HISTORY OF INTELLECTUAL PROPERTY RIGHTS IN THE WORLD

Intellectual Property can be traced to its roots in England about 300 to 400 years ago, with British Statute of Anne 1710 and statute of monopolies originally created not as intellectual property statute but ultimately as a way to encourage learning and to keep the monarchy, which was so relatively powerful that time from being able to censor and control what was published.

In **1883, Paris Convention** for the **Protection of Intellectual Property** was set forth as an international agreement **to help creators in ensuring that their intellectual works are being protected in other countries.**

In **1887, Berne Convention** for the **Protection of Literary Work and Artistic Works** was approved and agreed to give rights to the creator to control and receive the payments of their work on the international level and arena.

In 1893, BIRPI (the United International Bureaux for the Protection of Intellectual Property) was formed with the amalgamation and submergence of the two secretariats set up to administer Berne and Paris Conventions.

In 1970, **BIRPI transformed into WIPO** (World Intellectual Property Organisation), which is an intergovernmental organisation with 193 member countries based in Geneva, Switzerland.

Later in **1974, WIPO, by joining the UN,** becomes a specialised agency thereby increasing the relevance of intellectual property.

WIPO was basically established to deal with issues of intellectual property particularly work involving creativity and innovations and the protection of traditional knowledge and culture.

19.4 IPR IN INDIA

19.4.1 Historical Perspective in India

Intellectual property in India has gone through a series of developments, which can be better understood as follows:

- In 1856, this Act of 1856 gave protection to inventions based on British Patent Law (1852), which gave certain exclusive privileges to inventors for a period of 14 years.
- In 1911, Patents and Designs Act was introduced.
- In 1972, The Patents Act (Act 39 of 1970) came into force in the same year.
- **In 1995, India joined World Trade Organisation (WTO).**

INTELLECTUAL PROPERTY RIGHTS (IPR)

WHAT IS INTELLECTUAL PROPERTY RIGHTS (IPR)?

- IPR stands for Intellectual Property Rights. It refers to the legal rights granted to individuals or organizations for their creative and innovative works.
- Intellectual property (IP) encompasses a broad range of intangible assets that are a result of human intellect and creativity. These assets can include inventions, literary and artistic works, designs, symbols, names, and images used in commerce.
- The primary purpose of IPR is to provide creators and inventors with exclusive rights over their intellectual creations.
- These rights enable them to protect their work from unauthorized use, reproduction, or exploitation by others.
- IPR encourages innovation, creativity, and economic growth by providing incentives and rewards to individuals or companies for their inventions, designs, or creative expressions.
- Effective IPR systems help foster innovation, promote economic growth, and encourage investment in research and development. They strike a balance between rewarding creators and inventors and facilitating the dissemination of knowledge and technology. Intellectual property laws and regulations vary across countries, and obtaining and enforcing IPR can involve legal procedures and enforcement mechanisms.
- Overall, IPR plays a crucial role in protecting and promoting intellectual creations, providing the legal framework for innovation, creativity, and economic development in various industries and sectors.

PATENTS

- A Patent is a statutory right for an invention granted for a limited period of time to the patentee by the Government, in exchange of full disclosure of his invention for excluding others, from making, using, selling, importing the patented product or process for producing that product for those purposes without his consent.
- The term of every patent granted is 20 years from the date of filing of application.
- The patent system in India is regulated by the Patents Act, 1970. The Patent Rules are regularly amended in consonance with the changing environment, most recent being in 2016.
- Patent protection is a territorial right and therefore it is effective only within the territory of India. There is no concept of global patent.
- An invention relating either to a product or process that is new, involving inventive step and capable of industrial application can be patented.

GEOGRAPHICAL INDICATION (GI) TAGS

- Geographical Indications of Goods are defined as that aspect of industrial property which refer to the geographical indication referring to a country or to a place situated therein as being the country or place of origin of that product.
- Typically, such a name conveys an assurance of quality and distinctiveness which is essentially attributable to the fact of its origin in that defined geographical locality, region or country.
- It is an indication. It originates from a definite geographical territory. It is used to identify agricultural, natural or manufactured goods. The manufactured goods should be produced or processed or prepared in that territory. It should have a special quality or reputation or other characteristics
- The registration of a geographical indication is valid for a period of 10 years.

INDUSTRIAL DESIGNS

- A 'design' refers to the visual aspects such as shape, configuration, pattern, ornamentation, lines, or colors applied to an article, whether in two-dimensional or three-dimensional form. The design is judged solely by the eye and should appeal to aesthetic considerations.
- It is registered Under the Designs Act, 2000.
- The duration of the registration of a design is initially ten years from the date of registration.

BENEFITS OF INTELLECTUAL PROPERTY RIGHTS (IPR)

Incentivizes Innovation and Creativity: IPR provides creators and inventors with exclusive rights over their creations, inventions, or discoveries. This creates an incentive for individuals and companies to invest time, effort, and resources in research and development, leading to the generation of new ideas, technologies, and artistic works.

Protection of Investment: IPR safeguards the investments made by individuals or organizations in developing and commercializing their intellectual creations. It ensures that others cannot easily copy or exploit their innovations or creative works without authorization. This protection encourages investment in new products, processes, or services, as it provides a potential return on investment through exclusive rights.

Economic Growth and Competitiveness: IPR is closely linked to economic growth and competitiveness. Industries that rely on innovation and intellectual property, such as technology, pharmaceuticals, and creative industries, contribute significantly to national and global economies. IPR protection fosters a favorable environment for these industries, attracting investments, promoting entrepreneurship, and driving economic development.

Encourages Technology Transfer and Collaboration: IPR can facilitate technology transfer and collaboration between different entities. It provides a framework for licensing agreements and partnerships, allowing for the transfer of technology, knowledge, and expertise. This leads to the dissemination of innovation, adoption of new technologies, and the development of new products or services.

Consumer Protection and Trust: IPR helps ensure the quality and authenticity of products or services. Trademarks, for example, enable consumers to identify and distinguish brands they trust and associate with specific qualities. Copyrights protect against unauthorized copying or distribution of creative works, ensuring that consumers receive genuine and original content.

Preservation of Cultural Heritage: IPR can safeguard and preserve cultural heritage, traditional knowledge, and indigenous practices. By recognizing and protecting traditional cultural expressions, IPR helps maintain cultural diversity, respect traditional communities' rights, and prevent misappropriation or unauthorized use of cultural resources.

Encourages Public Disclosure and Information Sharing: Many IPR systems require creators to disclose information about their inventions or innovations in patent applications or copyright registrations. This information becomes publicly available, contributing to the pool of knowledge and encouraging further research, innovation, and development in related fields.

International Cooperation and Standards: Intellectual property laws and regulations are often harmonized at the international level through agreements and treaties. This promotes cooperation, facilitates trade, and sets global standards for IPR protection and enforcement, ensuring a level playing field for businesses and encouraging cross-border collaboration.

COPYRIGHT ©

- Copyright is a legal right that protects creators of various works. It includes rights such as reproduction, communication to the public, adaptation, and translation. The main purpose is to safeguard and reward creativity, which is vital for the progress and development of society. By protecting the rights of authors, artists, musicians, and others, copyright fosters an environment that encourages creativity and motivates both creators and the wider community to generate new works.
- Copyright typically lasts for 60 years.
- For literary, dramatic, musical, and artistic works, it is counted from the year after the author's death.
- For cinematograph films, sound recordings, photographs, posthumous publications, anonymous and pseudonymous works, and works of government and international organizations, the 60-year period is calculated from the date of publication.

TRADEMARK (TM)

- A trademark, also known as a brand name, is a visual symbol such as a word, name, device, label, numerals, or combination of colors used by a business to differentiate its goods or services from those of other businesses. To register a trademark under the law, certain requirements must be met:
  - a. The chosen mark should be capable of being represented graphically, typically on paper.
  - b. It should have the ability to distinguish the goods or services of one business from those of others.
  - c. The mark should be used or intended to be used in connection with goods or services to indicate a trade connection between the goods/services and a person who has the right to use the mark.
- The registration of a trade mark, after the commencement of this Act, shall be for a period of ten (10) years, but may be renewed from time to time in accordance with the provisions of this section.
- The Trademark in India was governed by Trade Marks Act, 1999.

- **In 1998, India joined Paris Convention.**
- In 1999, Patents Amendment Act came into force.
- In 2002, The Patents Amendment Act 2002 came into force.
- In 2003, Second Amendment Act in Patents Act was proposed with terms of patent as 20 years after 18 months of publication and setting up of patent tribunal in Chennai.
- **Patents Amendment Act, 2005 came into force with effect from 1 January 2005.**

Due to the significant changes in the country's economic and political situations after India's independence, in the year 1949, the Union Government formed a committee under the leadership of Justice **'Dr. Bakshi Tek Chand'**, retired judge of High Court of Lahore **for reviewing the country's patent law** and for ensuring the contribution of the patent law towards the national interest.

Dr. Bakshi Committee submitted its report on 4 August 1949, with recommendations for the prevention of abuse or misuse of patent rights in India, and also suggested amendment to Sections 22, 23, 23A of the Patents and Design Act, 1911, on the lines of United Kingdom Act 1919 and 1949. It was also observed that the Patent Act should contain clear indications so as to ensure food and medicine and curative and surgical devices are made available to the people at the cheapest price with proportionate and reasonable compensation to the patentee.

So, in accordance with the recommendations of Dr. Bakshi Committee, the Act of 1911 got amended in 1950 in relation to working of inventions and compulsory licence or revocation. Another amendment was passed in 1952 for providing compulsory licence in relation to patents in insecticide, fungicide, food, medicines and any invention of surgical and curative devices.

In 1957, Justice **'N. Rajagopala Ayyangar' Committee was appointed for examining the questions of revision of the Patent Law and advising the government accordingly**. The Report submitted by the Committee had two parts: one dealing with patent law and the other with detailed note on lapsed Bill of 1953. The Committee recommended the patent system for the stay or retention, despite its shortcomings. On the basis of the Committee recommendations, Patents Bill 1965 was introduced, which later got lapsed.

In 1970, Patents Act 1970 was passed and replaced the 1911 Act concerning Patent Law 1911, which still continued to be applicable to designs. Patents Act 1970 came into force on 20 April 1972 with the publication of Patents Rule 1972.

The Patents Amendment Act 1999 was brought to force from 1 January 1995, providing filling of applications for product patents in areas of pharmaceuticals, drugs and agro-chemicals, though such patents were not allowed.

Patents Amendment Act 2002 came into force from 20 May 2003, replacing the Patents Rule 1972 with the new introduced Patents Rules, 2003.

Patents Amendment Ordinance, 2004 was enforceable from 1 January 2005, which later got superseded by Patents Amendment Act 2005.

19.4.2 National Intellectual Property Right Policy

It is the first policy of India on IPR, which was revealed by the Finance Minister (Union Government) in accordance with TRIPS in May 2016. So far, only specific Act regulates the IPR in India. **CIPAM (Cell for IPR Promotion and Management), a professional body created under DIPP, has been entrusted with the implementation of the National IPR Policy 2016.** It is a vision document, which aims to create and exploit synergies between all forms of intellectual property, concerned statutes and agencies.

The policy, which is in compliance with WTO's (World Trade Organisation) agreement on TRIPS (Trade Related aspects of IPRs), aims to sustain entrepreneurship and boost **'Make in India'** scheme.

MAIN OBJECTIVES OF IPR POLICY IN INDIA

- IPR Awareness and outreach
- Stimulating the IPR generation
- Strong legal and legislative framework
- Modernise and strengthen service-oriented IPR administration
- Commercialisation of IPR
- Enforcement and adjustment for combating IPR adjustment
- Human Capital Development for teaching, training, research and skill-building in IPRs

19.4.2.1 Highlights of New Intellectual Property Policy

- The said Policy aims towards the protection of public interest through the promotion of IPR as a profitable financial asset; and further encouraging the innovation and entrepreneurship.
- There will be **reviewing of plan after every five years** in discussion with stakeholders.
- Various steps, such as reviewing of the present IP laws, their revision and improvisation for the removing of abnormalities and discrepancies, is required to be undertaken in order to have strong and effective IPR laws.
- There is complete conformity of policy in accordance with WTO's agreement on TRIPS.
- There should be special focus on creation of IPRs awareness and its effective enforcement, in addition to persuading of IP merchandising with the help of different incentives.
- India will participate gainfully in international treaties and agreements negotiations in discussion with stakeholders. According to the policy, there will be evaluation of the country's consent to few multilateral treaties, which are in its interest, by the government and become a party to those treaties, which the country has actually implemented for facilitating it in its decision-making process.
- As per the policy proposal, for all the IPR related issues, the nodal agency will be the **Department of Industrial Policy and Promotion (DIPP).** Moreover, **DIPP will also be responsible for tackling of all the copyrights related issues in place of the Human Resource Development (HRD) Ministry.**
- There is a rationalisation of **trademark offices for reducing the examination and registration time to just 1 month by the year 2017.** There is hiring of approximately 100 new examiners for trademarks by the government and there is **reduction of trademarks evaluation time from 13 months to 8 months, and ultimately bringing it to one month by March 2017.**
- There will be the coverage of films, music and industrial drawings under the copyright.
- The policy helps in the filing of domestic IPR from IPR generation to commercialisation and further helps in promoting the research and development through tax benefits.
- The **policy also facilitates** in the creation of **an effective loan guarantee scheme** for the promotion of start-ups.
- **As per the policy, the country will persist** in the utilisation of the legislative space and **flexibilities offered in international treaties and the TRIPS Agreement.** These flexibilities consist of the **usage of provisions like Section 3(d) and compulsory licences (CLs) under the country's sovereign rights to ensure the availability of essential and life-saving drugs at affordable prices.**
- Due to the policy, the patent laws of the country remain intact and there is no opening up of Section 3(d) of the Patents Act, setting the standards in the country for reinterpretation.
- **In the field of compulsory licencing, the CL has been issued in the country only for a cancer drug.** As per Mr. Jaitley, the country rarely exercises this power. This being considered as significant statement as the developed countries, such as the US, have raised their apprehensions over the country's issuance of the CL. According to the standards of the WTO, a government in public interest can raise CL allowing a company for making a patented product without the patent owner's permission. **As per the Indian Patents Act, a CL can be raised in the category of a drug if any medicine seems to be not reasonable, and the permission for drug manufacturing is given by the government to the qualified generic drug manufacturer.**
- In view of the financial support on the export and sale of the items on the basis of IPRs produced from the research being publically funded is the outcome of the IPR policy, ultimately benefitting the government.

19.4.2.2 Compulsory Licencing

- Compulsory licences are **authorisations given to a third-party by the Controller General to make, use or sell a particular product or** use a particular process which has been patented, without the need of the permission of the patent owner.
- This concept is recognised at both national as well as international levels therefore relevant

provisions can be found in both **Indian Patents Act 1970 and the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS).**

- The **application for compulsory licence can be made to the Controller on expiry of 3 years** upon fulfilment of any of the three conditions mentioned in section 83 of the Indian Patents Act, 1970.
- Compulsory licences can also be issued suo motu **by the Controller of Patents under section 92,** pursuant to a notification issued by the Central Government **if there is either a 'national emergency' or 'extreme urgency' or in cases of 'public non-commercial use'.**

First Licence Issued

- **India's first ever compulsory licence was granted** by the Patent Office **on March 9, 2012,** to **Hyderabad-based Natco Pharma for the production of generic version of Bayer's Nexavar,** an anti-cancer agent used in the treatment of liver and kidney cancer.

Global Perspective on Compulsory Licencing

- This phenomenon of compulsory licencing is a hugely debated issue. **Many developing countries are giving importance to the compulsory licencing because of the unavailability and unaffordability of the medicines,** and they are continuously granting more and more compulsory licences. **The developed countries of Europe, USA are opposing this view as it would make innovation difficult for the pharmaceutical companies.**

Recent News

- **Issue compulsory licences for manufacture of an affordable generic version of Remdesivir, CPI(M) tells government.**
- It said the government should invoke **section 92 of the Patent Act** that allows it to issue **compulsory licences so that Indian manufacturers can produce a more affordable generic version.**

Need for Compulsory Licencing

- **'Gilead Sciences' (a pharmaceutical company)** anti-viral drug **Remdesivir has shown efficacy in treating COVID-19 patients.**
- **Media reports indicate that the US, which was hoarding all drugs found to be useful in combating the pandemic, had bought the entire stock of Remdesivir from Gilead for future months. It will therefore not be available for the rest of the world.**
- Besides, while the cost of manufacturing Remdesivir for a full course – as worked out by experts – is less than $10 or ₹750 in the US and about ₹100 in India. Gilead, by virtue of its patent monopoly, is holding the world to ransom by asking a price that is hundreds of times its cost.

19.4.3 Steps Taken by Government to Improve the Intellectual Property Rights Ecosystem in India

- A comprehensive national IPR policy has been put in place.
- Integrated approach and synergy had been adopted through transferring various IP offices and Acts under DIPP and also merging Copyrights Board with Intellectual Property Appellate Board.
- Cell for IPR Promotion and Management has also been established for assisting in simplifying and streamlining of IP processes as well as creating IPR awareness, commercialisation and enforcement.
- A scheme for facilitating Start-up Intellectual Property Protection (SIPP) has been launched for encouraging innovation and creativity of Start-Ups.
- **India has also become the 90th member of Madrid Protocol.**

MADRID PROTOCOL

- It is an international treaty that allows a **trademark owner to seek registration in any of the countries that have joined Madrid Protocol by filing a single application.**
- International Bureau of the World Intellectual Property Organisation administers the international registration system.

- The Department of Industrial Policy and Promotion (DIPP) has inked agreement with Punjab State Council of Science and Technology to establish India's first TISC (Technology and Innovation Support Centre).
- TISC is WIPO's (World Intellectual Property Organisations) programme that provides

innovations in developing countries with access to locally based high-quality technology, information and related services.

- The programme will help innovators to fully exploit their creative potential and also protect their IPRs.
- CIPAM (Cell for IPR Promotion and Management) has been designated as the national focal point for the TISC networks.
- Scheme for IPR Awareness Creative India; Innovative India has been launched by CIPAM to raise IPR awareness across India.
- CIPAM has also launched 'IPrism', an Intellectual Property Competition for college and university students to foster a culture of innovation and creativity.

CELL FOR IPR PROMOTION AND MANAGEMENT (CIPAM)

With the slogan of 'Creative India; Innovative India', the Government approved CIPAM, a professional body under the aegis of DIPP to take forward the implementation of the National IPR Policy in May 2016. **CIPAM has been created to work towards public awareness of IPRs, promotion in filing of IPRs, to provide various inventors to commercialise their IP assets.** CIPAM also works for implementing the National IPR Policy, in collaboration with various Government Ministries/Departments and other stakeholders.

'IPRISM' AND ITS ISSUE IN INDIA

It is an Intellectual Property (IP) Competition to promote a culture of innovation and creativity in the younger generation at college and university-level students. **Iprism promotes young creators and provides unique opportunity in their creations.** Iprism launched various bodies: The Cell for IPR Promotion and Management (CIPAM), Department of Industrial Policy and Promotion (DIPP), in collaboration with ASSOCHAM and ERICSSON India. This competition encourages students in submitting piracy and counterfeiting-based films under dual 30 and 60 seconds categories and further on gaming mobile applications. Due to the piracy and counterfeiting, the industry is encountering a considerable loss and thereby posing serious safety threats to the consumers. This type of awareness will help tackle such types of crimes as the little knowledge on piracy and circulation of fake items leads to negative socio-economic impacts on the society.

19.5 LIMITATIONS OF IPR

According to the critics of intellectual property, it is harming health of new creations, preventing progress and providing benefits to concentrated masses only.

As per the critics, intellectual property harms the public interest by its wide control of copyright extensions and other patents.

Some critics also believed that if property rights in information and ideas are allowed, then artificial scarcity would be created. Another opinion is that intellectual property needs to be expanded, in duration as well as in scope.

19.6 TRIPS AGREEMENT

TRIPS agreement is an agreement at the international level, governed and administered by the World Trade Organization (WTO), which sets some basic and minimum standards for Intellectual property. The very first of its kind, an agreement was prepared to provide International Law for Intellectual Property and the agreement was on TRIPS. It comes under Article (4) of WTO provisions, and provides protection to all the member countries of WTO in terms of copyrights, producers of broadcasting organisations, trade dress, geographical indication, designs and all other patents, etc. It was concluded in Uruguay round of GATT 1994.

19.7 COPYRIGHT AND RELATED RIGHTS

19.7.1 Provision of Copyright and its Related Rights

The Law of Copyright grants legal protection to the work of authors, artists and other creators. A closely linked field is 'Related Rights', which cover rights similar to copyright, but are limited, for they last for very short time as their durations are short. **In 'Related Rights' creators included are actors, musicians in their act; producers of phonograms in their sound recordings; and broadcasting organisations in their radio and TV programmes.**

The Copyright Act 1957 was administered by HRD ministry, but after approval of national policy, this Act is now administered under Department of Industrial Policy and Promotion (DIPP). The DIPP was established in 1995 under the Ministry of Commerce.

Following are the main areas of DIPP:

- India's Industrial Policy Formulation and Implementation.
- The FDI policy Formulation and Amendment.
- Industrial Promotion.
- Intellectual Property Rights Policy Formulation and Implementation.

DEPARTMENT OF INDUSTRIAL POLICY AND PROMOTION (DIPP)

It was set up in the year 1995 and the Department of Industrial Development was merged with DIPP in the year 2000 working under the Ministry of Commerce and Industry, Government of India. Considering the national priorities and socio-economic goals, **DIPP facilitates the industrial sector growth through the formulation and implementation of promotional and developmental measures and also liable for assisting and raising the country's FDI flows.** The department is also responsible for the items intellectual property rights in relation to patents, designs, trademarks and geographical indication and further manage the actions in linkage to their encouragement and protection. DIPP is now called as Department for Promotion of Industry and Internal Trade (DPIIT).

19.7.2 Rights Provided and Assured by 'Copyright and Related Rights'

Copyright holders are given some basic rights under the Copyright law as follows:

- Copyright holders can grant or allow others if agreed upon to use their work, this is the exclusive right of the copyright holder.
- They are also given the right to give authorisation or restriction/prohibition of the reproduction of their work, which includes printing, recording, public acting, broadcasting; translation into other languages, adaptation, for instance, making a film's screenplay from a novel.
- Sound recordings, publications, films, etc., which are some of the sources for mass distribution and financial investment and communication, which are required by copyright holders so as to achieve success in their various works.

So, in these types of works, generally, the creator transfers the rights to companies for the betterment of their work. The companies then in return compensate them, giving a percentage of revenues generated from their work as royalty.

Economic Rights of Creator lasts for a limited period of 50 years approximately after the Creator's death, this is as per the copyright law (as relevant in the WIPO Treaty). Although, national laws may vary and can give protection for long-term duration. With this term period, the creator and their heirs and successors both were financially benefited. Related rights are protected for short durations, commonly 50 years after the work's performance, recording or broadcasting.

The enforcement of rights under copyright and related rights laws by the right holders can be undertaken with the help of a variety of means, such as civil act suits, administrative remedies and criminal prosecution. In order to enforce such rights, there is need of restrictions, orders involving destruction of infringing items, inspection orders, etc.

To enforce the rights given to copyright holders under the 'Copyright and Related Rights Laws' they can use methods, which include civil action suits, injunctions, inspection orders and administrative remedies and others.

19.7.3 Benefits of Protecting Copyright and Related Rights

Protection of these rights is important for nurturing and growth of creativeness in humans with improved innovation. It gives recognition along with fair economic reward to creators and also increases their willingness to do such works in future. So, the companies and individual with the assurance of rights granted invest more faithfully in the creation. This, in turn, helps in encouraging and pushing towards socio-economic development of every nation.

19.7.4 Copyright and Related Rights in Relation with Advancement in Technology

Advancement and development of technology brought new ways of spreading/dispersing of creations by various communication, which can be broadcasting through satellites, cassettes, etc. As a result of the released/spreading of work done through Internet, there have been questions raised on the copyright and related rights in the world. World Intellectual Property Organisation is highly concerned regarding this international debate for shaping new and fresh standards for the safeguard of copyrights in cyberspace. WIPO Performances and Phonograms Treaty (WPPT) and World Intellectual Property Organisation Copyright Treaty (WCT) are administered by 'INTERNET TREATIES' Organisation. Prevention of unauthorised access to and use of creative works on the Internet is the main aim of the above treaty.

Delhi High Court Copyright Judgement (DU Photocopy Case)

On December 9, 2016, the ruling was no restriction books can be photocopied, as long as 'justified by the demands of the course'. Under Section 52(1)(i) of the Copyright Act, photocopying material, which is copyrighted for using/usage purpose 'in the course of instruction', is permitted. The court concluded that 'qualitative and quantitative' tests for fair use are not included in the law.

The large publishing companies such as Oxford University Press and Cambridge confronted the University of Delhi and its photocopier for violation of copyright. As per the Delhi High Court ruling, the course pack photocopying for the education point is within the restrictions of law.

Photocopying, in itself, does not lead to violation of copyright. According to the court, copyright is to create equilibrium between challenging ideas of private and public interests.

The software programming can be considered as a 'literary work'. According to the Copyright Act, 1957, there is inclusion of software programmes, tables and compilations, including databases as literary work. In order to register the software products' copyright, along with the application, source code has also to be submitted.

19.8 TRADEMARK

As per WIPO, a trademark is a sign capable of distinguishing the goods or services of one enterprise from those of other enterprises. This implies that a trademark can be a **word, signature, name, device, label, numerals or combination of colours** used by one undertaking on goods or services or other articles of commerce to distinguish it from other similar goods or services belonging to a different undertaking.

The legal requirements to register a trademark under the Trade Marks Act, 1999 are:

1. The selected mark should be capable of being represented graphically (that is in the paper form).
2. It should be capable of distinguishing the goods or services of one undertaking from those of others.
3. It should be used or proposed to be used as a mark in relation to goods or services for the purpose of indicating or so as to indicate a connection in the course of trade between the goods or services and some person have the right to use the mark with or without identity of that person.

19.8.1 Different Types of Trademarks that may be Registered in India

- Any name (including personal or surname of the applicant or predecessor in business or the signature of the person), which is not unusual for trade to adopt as a mark.
- An invented word or any arbitrary dictionary word or words, not being directly descriptive of the character or quality of the goods/service.
- Letters or numerals or any combination thereof.
- The right to proprietorship of a trademark may be acquired by either registration under the Act or by use in relation to particular goods or service.
- Devices, including fancy devices or symbols.
- Monograms.
- Combination of colours or even a single colour in combination with a word or device.
- Shape of goods or their packaging.
- Marks constituting a 3-dimensional sign.
- Sound marks when represented in conventional notation or described in words by being graphically represented.

19.8.2 Registrar

- The Controller General of Patents, Designs and Trade Marks heads the TRADE MARKS Registry offices and functions as the Registrar of TRADE MARKS.

19.8.3 Intellectual Property Appellate Board (IPAB)

- It was constituted on September 15, 2003 by the Indian Government to hear and resolve the appeals against the decisions of the registrar under the Indian Trade Marks Act, 1999 and the Geographical Indications of Goods (Registration and Protection) Act, 1999.
- Since April 2, 2007, IPAB has been authorised to hear and adjudicate upon the appeals from most of the decisions, orders or directions made by the Patent Controller under the Patents Act. Therefore, all pending appeals of Indian High Courts under the Patents Act were transferred to IPAB.
- **Organisation of an IPAB Bench:** Each Bench of the IPAB includes a Judicial Member and a Technical Member.
- The qualifications for appointment as a technical member of the IPAB are mentioned in the Trade Marks Act and the Patents Act.
- **Jurisdiction:** Appeals from the order or decision of the Registrar shall be made to the IPAB within a period of three months from the date on which the order or decision sought to be appealed against is communicated to the person preferring the appeal. An extension is available for filing the appeal provided the person appealing satisfies the Board that he had a sufficient cause for not preferring the appeal within the stipulated time period.
- The **Intellectual Property Appellate Board (IPAB)** has rejected a plea from Red Bull, manufacturer of an energy drink, for the removal of a trademark registered in the name of Dr. Reddy's Laboratories Limited.

19.8.4 Red Bull's Plea on Trademark Rejected

- In its petition, Red Bull claimed to be a pioneer in using the concept of an animal/human acquiring wings after consumption of the Red Bull Energy Drink and hence for the tagline **'Gives You Wings'** they are the registered proprietor in India.
- **They pointed out that another trademark which was registered in November 2001 with the tagline 'Your Wings to Life', in the name of Dr. Reddy's Laboratories Limited** have not undertaken any activity to commence use of the impugned registration and hence sought for its cancellation.
- IPAB stated 'The rival trademarks are neither deceptively similar nor identical with. The applicant mark 'Your Wings to Life' is not the main mark. It is the sub-brand. Therefore, the goodwill and reputation alleged by the applicant is not pertaining to the main mark Red Bull'. Hence, both trademarks are not similar and the petition got dismissed.

19.9 PATENT

19.9.1 Concept of Patent

It is a special right given for an invention. The invention can be a process or a product that brings an unusual way of doing something, or that provides a scientific solution to a problem. Duration for protection of the invention is limited and generally restricted to 20 years.

19.9.2 Importance of Patent

Patent rewards individuals by recognising their creativity and by offering incentives to their inventions and improving the quality of human life by motivating and encouraging further innovation.

19.9.3 Protection of Different Types of Patents

It safeguards inventions by giving the rights to the owner and making sure that without their consent, the invention cannot be commercialised. Court holds the enforcement rights of the patents and the authority to stop infringement of the patent. The court also holds the right to declare a patent as invalid after successful challenge by a third party.

19.9.4 Rights of Patent Owners

The owner has the right to take decisions on who can use its invention on mutually agreed terms for any particular time period. It also has the right to sell their invention, if they wish to do so. After some fixed duration of time, patents get expired; which means that there is ending of patent protection and further, the entering of invention into the public realm is termed as becoming off patent. After that, there are no limited rights of owner on the invention, and so the invention is easily available for commercial exploitation by the public.

19.9.5 Importance of Patents in Everyday Life

Patented inventions are deeply intact with human life, from sewing machines (patented held by Howe and Singer), to magnetic resonance imaging (MRI) (patented by Damadian) to electric lightning (patented by Edison and Swan) and the iPhone (patented by Apple). All patent owners, for enriching the total technical knowledge in the world, publically disclose information of the invention. This will enhance more creation and innovation. Hence, the patents provide valuable information and inspiration for future generations of researchers and inventors with the protection of the patent owner.

.9.6 Patent Granting

For a safe and secure patent, a patent application needs to be filed. The application must mention the title of the invention and indication of the technical field from which it belongs. The description and background of the invention must be included in clear language so that an individual with nominal understanding of the field could also reproduce the invention. Visual materials that may help in the better understanding of invention are generally used, such as diagrams or drawings. Patent application should contain different 'claims', which will help in determining the extent of protection to be given by the patent.

Patent is generally granted by the regional patent offices or national patent office, such as the African Intellectual Property Organisation (AIPO) and the European Patent Office (EPO). These provide protection to an invention for one or more countries.

WIPO administers the Patent Cooperation Treaty (PCT), which eliminates the need of filing various applications providing a single international patent application similar to the national applications filed in the designated countries. An applicant seeking for protection may file an application and request for protection in as many signatory states as needed.

In India, Department of Industrial Policy and Promotion, Ministry of Commerce and Industry, under The Patents Act, 1970 (as amended in 2005), administers patents.

19.9.7 Protection of Invention

Conditions for an invention to be protected by a patent are:

- Invention should be of practical usage.
- Patent should be novel.
- An 'inventive step' needs to be shown by the invention.

19.9.8 Highlights of India's Patent Policy 2016

The policy is in compliance with the WTO's agreement on TRIPS and in particular the focus is being laid in the policy on awareness generation on IPRs and its enforcement in an effective manner, in addition to IP commercialisation promotion with the help of different incentives.

INDIAN PATENT ACT, 1970 AND 2005

The main **purpose of patent** system is to encourage innovation and eventually results in technological development. The present **Patents Act, 1970** came into force in the year 1972, amending and incorporating the existing **laws** relating **to Patents** and Designs **act** 1911 in India.

Section 3(j) of the **Patents Act 1970** states that 'plants and animals in whole or any part there of other than microorganisms but including seeds, varieties and species and essentially biological processes for production or propagation of plants and animals' are **not inventions as per** the act and hence **not** patentable.

The Patent (Amendment) Act 2005 came into force from 1st January 2005, which brought changes in the previous patent system of India wherein product patent was extended to all subjects of technology consisting of food, drugs, chemicals and microorganisms. Moreover, Section 3(d) introduced in to the said amendment act 2005 and introduces pharmaceutical product patents in India for the first time. The Patent (Amendment) Act 2005 defines what invention is and makes it clear that any existing knowledge or thing cannot be patented. The provision defines that a 'novelty' standard – which, along with 'non-obviousness' or 'inventive step' and industrial applicability, are the three prerequisites for 'patentability'. 'Discovery' essentially refers to finding out something which already existed in nature but was unknown or unrecognised. Therefore, discoveries are excluded from patent protection under section 3 of the Indian Patent Act 1970.

- The Department of Industrial Policy and Promotion has been made the nodal agency for all IPR-related issues and issues linked to copyrights have also been shifted to DIPP from that of the Human Resource Development Ministry.
- There is a rationalisation of trademark offices for reducing the examination and registration time to just 1 month by the year 2017.
- There is reduction of trademarks evaluation time from 13 months to 8 months, and ultimately bringing it to one month by March 2017.
- The policy helps in filing of domestic IPR from IPR generation to commercialisation and further helps in promoting the research and development through tax benefits.
- The policy also facilitates in the creation of an effective loan guarantee scheme for the promotion of start-ups. As per the policy, the country will persist in the utilisation of the legislative space and flexibilities offered in international treaties and the TRIPS Agreement. These flexibilities consist of the usage of provisions like Section 3(d) and CLs under the country's sovereign rights to ensure the availability of essential and life-saving drugs at affordable prices.
- In the year 2013, the Supreme Court had upheld the decision of Intellectual Property Appellate Board regarding the rejection of giving patent protection to the application of Novartis for a new drug form termed as imatinib but branded as Glivec. Novartis had challenged Section 3(d) of the country's patent act, which guarantees that the companies do not get the patent protection by merely altering the already existing drug without there being any subsequent changes in its healing effects. At the time of giving decision, Section 3(d) of the Indian Patents Act, 1970 was validated by the Supreme Court. Moreover, the court noted the product named as beta crystalline had already been identified earlier to the year 1995, with the past patent being held by the Novartis. The outcome of the decision is that the country's patent law was completely upheld and the granting of patents will be undertaken only for authentic innovation and there will be no acceptance of any litigative patenting. This means that the patent cannot be granted if any old molecule is kept in a new substance, just creating a minor modification, and presenting it as an entirely new invention.
- The creation of trivial modifications into the original product for the claiming of another patent to extend the period for the validation of patent is termed as the ever-greening of patents.
- The compulsory licencing (CL) has only been issued once for a cancer drug, Sorafenib to-sylate (Nexavar). As per the Indian Patents Act, a CL can be raised in the category of a drug if any medicine seems to be not reasonable, and the permission for drug manufacturing is given by the government to the qualified generic drug manufacturer.

19.9.9 Patent Prosecution Highway Programme

The Union Cabinet approved the proposal for adoption of ***Patent Prosecution Highway (PPH) programme*** by ***the Indian Patent Office (IPO)*** under ***the Controller General of Patents, Designs & Trade Marks, India (CGPDTM)*** with patent offices of various other interest countries or regions. PPH ***initially commenced between Japan Patent Office (JPO) and Indian Patent Office*** on pilot basis for a period of three years only continues in the pilot stage till date.

Eligibility

- Under this Pilot programme, Indian Patent Office may receive patent applications in certain specified technical fields only, namely, Electrical, Electronics, Computer Science, Information Technology, Physics, Civil, Mechanical, Textiles, Automobiles and Metallurgy while JPO may receive applications in all fields of technology.

What is PPH?

- The Patent Prosecution Highway (PPH) is a set of initiatives for providing accelerated patent prosecution procedures by sharing information between some patent offices.

PPH programme would lead to the following benefits for the Indian IP office:

1. Reduction in time to dispose patent applications.
2. Reduction in pendency of patent applications.
3. Improvement in quality of search and examination of patent applications.
4. Create an opportunity for Indian inventors including MSMEs and start-ups of India to

get accelerated examination of their patent applications in Japan.

19.9.10 Patenting in India

- The Union Government has the powers to formulate rules for the implementation of the Act and amending the administration of patent, according to Section 159 of the Indian Patents and Designs Act, 1970, and therefore the Patents Rules, 1972, were declared and amended under the Patents Amendment Rules, 2006.
- The government has made amendments to the rules and introduced methods for facilitating the start-ups as well as entities' patent applications evaluation, preferring India for the first patent filing. Moreover, there are around lakhs of patent applications pending in the country.
- The government is aiming to reduce the trademarks initial evaluation time from 13 to 8 months, and ultimately bringing it to one month by March 2017.

Secondary Patents and Its Recent Issue for India

About 1,700 rejections for pharmaceutical patents at the Indian Patent Office were applications that sought protection in the form of secondary patents for blockbuster medicines.

Secondary Patents

- The owners market is being offered by the patents exclusivity for a restricted time period. In case of medicines, the exclusiveness should last as long as the primary patent, which relates to the active pharmaceutical ingredient (API) of the medicine and is effective, particularly for 20 years.
- The patent cliff is being described as the ending of patent exclusivity as the prices of the drug subsequently drop sharply by 80 per cent due to generic competition.
- The pharmaceutical companies discover new ways due to the risk of their huge profit reduction, which made them delay their exclusivity through the filing of secondary patents for derivatives and variants of the API, such as a physical variant of the API, a new formulation, a dosage regimen, or a new method of administering the medicine.
- The secondary patents prop up before the expiry of a primary patent, thereby stretching the exclusivity beyond, a practice that is called 'evergreening'. This strategy is most lucrative when employed in the context of so-called blockbuster medicines, which reap annual revenues exceeding $1 billion.
- These provisions also extend to biologics, the new big players in the therapeutics marketplace. Biologics, due to their complex structure, offer more opportunities in secondary patenting for extending patent terms.

19.9.12 PepsiCo's Patent Issue

The **Protection of Plant Varieties and Farmers Rights** (PPV&FR) Authority has revoked a PVP (Plant Variety Protection) certificate granted to PepsiCo India Holding (PIH) on a potato variety (FL-2027) on various grounds.

This included the following

- The grant of the certificate of registration had been based on incorrect information furnished by the applicant.
- The certificate had been granted to a person not eligible for protection.
- The grant of the certificate of registration was not in the public interest.

What's the issue?

- In 2019, PepsiCo sued some Indian farmers, based in Gujarat for cultivating the FC5 potato variety, which has a lower moisture content required to make snacks such as potato chips.
- Withdrawing the lawsuits the same year, the New York-based company said it wanted to settle the issue amicably.
- Later, Kavitha Kuruganti, a farmers' rights activist, petitioned the PPV&FR Authority for revocation of intellectual protection granted to PepsiCo's FC5 potato variety, saying that India's rules do not allow a patent on seed varieties. Please note that Section 39 of PPV&FR Act, 2001 specifically says that a farmer is allowed to grow and sell any variety of crop or even seed as long as they don't sell branded seed of registered varieties.

The PPV&FR Act, 2001

- Enacted by India in 2001 adopting sui generis system.
- It is in conformity with International Union for the Protection of New Varieties of Plants (UPOV), 1978.
- The legislation recognises the contributions of both commercial plant breeders and farmers in plant breeding activity and also provides to implement TRIPs in a way that supports the specific socio-economic interests of all the stakeholders including private, public sectors and research institutions, as well as resource-constrained farmers.

Objectives of the PPV&FR Act, 2001

- To establish an effective system for the protection of plant varieties, the rights of farmers and plant breeders and to encourage the development of new varieties of plants.
- To recognise and protect the rights of farmers in respect of their contributions made at any time in conserving, improving and making available plant genetic resources for the development of new plant varieties.
- To accelerate agricultural development in the country, protect plant breeders' rights; stimulate investment for research and development both in public and private sectors for the development of new plant varieties.
- Facilitate the growth of seed industry in the country which will ensure the availability of high-quality seeds and planting material to the farmers.

Rights under the Act

- **Breeders' Rights:** Breeders will have exclusive rights to produce, sell, market, distribute, import or export the protected variety. Breeders can appoint an agent/a licensee and may exercise for civil remedy in case of infringement of rights.
- **Researchers' Rights:** Researchers can use any of the registered variety under the Act for conducting experiment or research. This includes the use of a variety as an initial source of variety for the purpose of developing another variety but repeated use needs prior permission of the registered breeder.
- **Farmers' Rights:**
    1. A farmer who has evolved or developed a new variety is entitled for registration and protection in like manner as a breeder of a variety;
    2. Farmers, variety can also be registered as an extant variety;
    3. A farmer can save, use, sow, re-sow, exchange, share or sell his farm produce including seed of a variety protected under the PPV&FR Act, 2001 in the same manner as he was entitled before the coming into force of this Act provided farmer shall not be entitled to sell branded seed of a variety protected under the PPV&FR Act, 2001;
    4. Farmers are eligible for recognition and rewards for the conservation of Plant Genetic Resources of land races and wild relatives of economic plants;
    5. There is also a provision for compensation to the farmers for non-performance of variety under Section 39(2) of the Act, 2001;
    6. The farmer shall not be liable to pay any fee in any proceeding before the Authority or Registrar or the Tribunal or the High Court under the Act.

19.10 COMPUTER-RELATED INVENTIONS (CRI)

- In February 2016, the Controller General of Patents, Designs and Trademarks Office declared a modified set of guidelines for the evaluation of Computer – Related Inventions.
- The latest guidelines are in order with the provisions of the Patents Act, 1970, excluding mathematical and business methods, algorithms and computer programmes from patentability.
- In order to promote stability in the patents field on computer-related inventions, the Controller General of Patents, Designs and Trademarks Office introduces Manuals and Guidelines for its evaluation at times.

The earlier guidelines in the field of patent made possible that the some software advancement could get a patent in comparison to the previous art, which could lead to the overflow of patents to be given in the software field. This could have created an adverse impact on the Indian IT industry, particularly the Indian start-ups, product companies, research organisations, a range of academics, organisations such as Society for Knowledge

Commons, Free Software Movement of India, which are at vanguard of innovation and have accepted the guidelines, which will further encourage innovation in the country.

19.11 INTELLECTUAL PROPERTY INDEX

The report on **International Intellectual Property Index 2018** (IIPI-2018) is released by the US Chamber of Commerce's Global Intellectual Property Centre (GIPC). It is an annual index, which examines a country's Intellectual Property (IP) framework across eight categories of indicators: patents, copyrights, trademarks, trade secret and market access, enforcement commercialisation of IP assets, systemic efficiencies and ratification of international treaties. It consists of 90 per cent of global gross domestic product and grades countries on patents, trademarks, copyrights, trade secrets, enforcement and international treaties.

Major Findings of the IIPI 2018

- According to the report, USA topped the list with 37.98 points with UK right behind at 37.97 and Sweden at 37.03 points.
- It has been noted in the IIPR Index 2018, economies which implement moderate improvement in the IP environment see positive economic and societal outcomes, ranging from access to financing and foreign direct investment to higher levels of economic value generation.
- India has been ranked 44 out of 50 countries, which was up from 43 out of 45 in the fifth edition.
- India's score has improved from 25 per cent (8.75 out of 35) of total score in the fifth edition to 30 per cent (12.03 out of 40) in the sixth edition, which is the highest improvement of any country measured.

19.12 INDUSTRIAL DESIGN

19.12.1 Basic Concept of Industrial Design

According to WIPO, 'A design may consist of three-dimensional features, such as the shape or surface of an article, or two-dimensional features, such as patterns, lines or colour'. A wide variety of products are included in industrial designs such as technical and medical instruments, appliances, vehicles, house ware, watches, etc. The condition for the protection under national law is that industrial design must be original/new and non-functional, which means that an industrial design is primarily of an aesthetic nature, and any technical features of the article to which it is applied are not protected by the design registration. However, a patent could protect those features.

19.12.2 Protection of Industrial Designs

- This gives an exclusive right against unofficial copying of the design by other third parties.
- It also promotes fair competition and honest trade practices, which benefit consumers too. Protection encourages the people to create more useful products, which benefit the people in general.
- It may also ensure a good return on investment, thereby encourage creativity in manufacturing as well as in traditional arts and crafts and industries. It also expands the export market of that nation.
- The small- and medium-sized enterprises as well as the craftsmen and individual artists, in both developed and developing countries, should have access to industrial designs.

Industrial design registration is under industrial design law for its protection. But, those designs which are 'new' or 'original' can only be registered. 'New' means no design is known to have existed previously with the similar or identical design. Protection is given generally for 5 years, with renewal possibility normally for 15 years.

Industrial design protection is generally bound to the concerned nation. The Hague Agreement, which concerns the International Registration of Industrial Designs and a WIPO-administered treaty, laid down the international designs registration procedure. The applicant needs an application to be filed in WIPO or in the regional office or national office of a state, which is a party to the treaty.

19.13 GEOGRAPHICAL INDICATION

As per WIPO, 'A geographical indication (GI) is a sign used on products that have a specific geographical origin and possess qualities or a reputation that are due to that origin. In order to function as a GI, a sign must identify a product as originating in a given place.

In addition, the qualities, characteristics or reputation of the product should be essentially due to the place of origin. Since the qualities depend on the geographical place of production, there is a clear link between the product and its original place of production'.

19.13.1 Advantages of Obtaining Protection for a GI

- Getting the protection for a GI enables the authorised user to take measures against the free riders who use it without permission and is benefited from its reputation.
- A geographical indication's reputation is an intangible asset which provides comfort to customers about the authenticity of that product.
- Protecting a GI is also a way to prevent registration of the indication as a trademark by a third party and to limit the risk of the indication becoming a generic term.
- It provides legal protection to Indian geographical signals which in turn promotes exports.

19.13.2 Who all can Apply for GI Registration?

- Any person, manufacturer, organisation or authority established by or under the law may apply for the registration of GI of their product.
- Post registration, their name should be entered in the Register of Geographical Indication as registered proprietor for the GI applied for.

19.13.3 Validity of Geographical Indication

- The registration of a geographical indication is valid for a period of 10 years and is required to be renewed by payment of a renewable fee.

19.13.4 Geographical Indications at the International Level

- Geographical Indications are covered as a component of intellectual property rights (IPRs) under the Paris Convention for the Protection of Industrial Property.
- GI is also governed by the World Trade Organisation's (WTO's) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). In India, Geographical Indications registration is administered by the Geographical Indications of Goods (Registration and Protection) Act, 1999 which came into force with effect from September 2003. The first product in India to be accorded with GI tag was Darjeeling tea in the year 2004–05.
- Geographical indication rights are territorial. This means that these rights are limited to the country (or region) where protection is granted. At present, no 'world' or 'international' geographical indication (GI) right exists.

19.13.5 Pakistan to Challenge India's Application for Exclusive GI Tag for Basmati Rice in EU

Pakistan has decided to file its opposition in the European Union in response to India's application for an exclusive GI tag to Basmati rice.

- The recently enacted statute of Geographical Indications (Registration and Protection) Act in Pakistan is the basis of Pakistan opposing Indian application for registration of Basmati rice exclusive rights. India has said that it is an Indian-origin product in its application, published in the EU's official journal on September 11, 2020.
- As per the EU's official journal, any country can oppose the application for registration of a name pursuant to Article 50(2)(a) of Regulations of the European Parliament and of the Council on quality schemes for agricultural products and foodstuffs within three months from the date of publication.
- Pakistan has claimed to be a major grower and producer of Basmati rice and hence pleading to declare India's application for exclusivity as unjustified.

Background

- In May 2010, GI status was given to basmati grown in Punjab, Haryana, Delhi, Himachal Pradesh, Uttarakhand and parts of western Uttar Pradesh and Jammu & Kashmir.

Note: Frequently, the GI and trademark are erroneously mistaken for each other and each year GI tag is being accorded on different varieties of new articles.

GI TAG SOUGHT FOR INDIA'S COSTLIEST MUSHROOM

A geographical indication (GI) tag has been sought for one of the costliest mushrooms in the world that grows in Jammu and Kashmir's Doda district by an NGO, Borderless World Foundation.

Key Points

- Locally called **Gucchi, or Morel,** the mushroom, priced at over 20,000 a kg, grows at an altitude of 2000 metres in cold environment of coniferous forest and collected by local people.
- It is said to have medicinal and nutritional properties and is a rich source of protein.

19.13.6 Difference Between a Geographical Indication and a Trademark

A trademark is a symbol used for distinguishing the company's goods and services from that of others and further grant certain rights to its owner in order to prevent others from using its trademark.

A geographical indication gives assurance to its consumers regarding the manufacturing of a product in a particular place and having unique characteristics related to the manufacturing place. The features of that particular place being nominated for GI tag are used by all manufactures related to that place.

19.13.7 Summary of the Basmati GI Tag Issue

- The Agricultural and Processed Food Products Export Development Authority, being a statutory body with the duty of promotion of export and development of a products variety, had submitted an application for the Basmati rice registration in respect of seven states in Indo-gangentic plain situated on the Himalayan foothills, under the Geographical Indications of Goods (Registration and Protection) Act, 1999.
- The Intellectual Property Appellate Board has instructed for the issuance of GI tag to Basmati Rice by the Chennai-based GI registry.
- The APEDA has included Madhya Pradesh for GI Basmati tag and subsequently, an application was filed with the registrar by Madhya Pradesh in resistance to APEDA.
- Contrary to that, the Intellectual Property Appellate Board was approached by APEDA for appealing against the order. In February 2016, there was a reversal of registrar's order by the IPAB regarding retreating the GI tag from APEDA. Presently, the order of IPAB is challenged in Madras High Court by the government of Madhya Pradesh.

19.13.8 Role of WIPO in the Protection of Geographical Indications

It administers international agreements like the Paris Convention and the Lisbon Agreement, dealing partially or entirely with protection of geographical indications (GI) at the international level.

19.13.9 Geographical Indications in India

The total products registered under GI in India are approximately 432 as per December 2022 Press Release by PIB. 'Darjeeling Tea' was the first product to be recognised in 2004. GI is administered under The Geographical Indications of Goods (Registration & Protection) Act, 1999. Till now, more than approximately 370 products were applied for the GI tag. (For all details and updates of GIs you may go to:

http://www.ipindia.nic.in

Some examples of GI from India are as follows:

1. Lucknow Chikan Craft
2. Mango Malihabadi Dusherai
3. Banaras Brocades and Sarees
4. Lucknow Zardozi Craft
5. Kannauj Perfume
6. Moradabad Metal Craft
7. Hyderabadi Haleem
8. Narayanpet Handloom Saree
9. Madurai Malli
10. Eartomozhy Tall Coconut
11. Thanjavur Veenai
12. Saleem Silk
13. Temple Jewellery of Nagercoil
14. Madurai Sungudi
15. Makarana Marble
16. Bikaneri Bhujia
17. Ganjam Kewada Flower

18. Naga Mircha
19. Nasik Grapes
20. Mahabaleshwar Strawberry

Note: As per the Madhya Pradesh government's profession, there is cultivation of Basmati rice in 13 out of its 51 districts and they are qualified to get the GI tag. Further, as per the recommendation of Agricultural and Processed Food Products Export Development Authority, the seven states were granted the Basmati GI tag.

19.14 PLANT BREEDER'S RIGHTS

These rights provide legal protection for the investment in plant breeding to develop new varieties. It is on the will of the breeders whether to apply for the plant breeder's rights or not, which provide royalties if any one uses the protected variety. It is a form of Intellectual Property Right, which protects the new variety of plants. Protection of new developed varieties of plants is an incentive to the breeder to get the benefits; moreover, it encourages the people to develop superior variety. Improved varieties are cost effective and high yielding, which are economically good for the farmers.

19.15 INDIAN SUPREME COURT SAYS SEEDS, PLANTS AND ANIMALS ARE NOT PATENTABLE

19.15.1 A Victory for the Planet

With the Supreme Court refusal to overrule a High Court decision of upholding Article 3(j) of Indian's Patent Law, has resulted into a key success in respect of biodiversity, planet, farmers seeds.

Article 3(j) excludes from patentability 'plants and Trade linked animals in whole or in any part thereof other than microorganisms but including seeds, varieties, and species, and essentially biological processes for production or propagation of plants and animals'.

The above article is an execution of TRIPs 27.3 b article. In a Treaty of Trade, Monsanto has brought life patents, whereas the government of India, Brazil and Argentina has omitted the patentability, as well as a sui generis option for varieties of plant protection. Monsanto tried to amend the TRIPs agreement for its own advantage, allied towards corporate interest and against the farmers, nations and their citizens interest.

19.15.2 Farmers Rights

India's representatives at the GATT were successful in bringing exclusions for plants and animals and a sui generis option in the TRIPS agreement and in India's Patent Act and its implementation. Therefore, Monsanto is producing a false claim in its SC appeal that the decision of High Court is in breach to the TRIPS agreement. Monsanto is contravening science in reference to science ad nauseam.

19.15.3 Genetic Modification is a Method not a Product

In Monsanto's argument, a gene is just a chemical and a plant is a machine where the chemical can be brought and removed mechanically as per our will. Further, as per Monsanto's misleading argument, Bt cotton is not a plant and modified Bt genes modified are not a plant or plant variety's division and their patent is for a 'product', not a 'process'.

However as per the Patent title clarification, patent is for 'methods for transforming plants to express *Bacillus thurengensis* delta endotoxins' and therefore Monsanto is arguing falsely that patent is a product patent and not a process patent.

As per the Monsanto, a chemical is being invented which transforms plants into superplants and the seed is just the box of the chemical.

Monsanto is deforming science at the basic level and further corrupting our laws by wrongly arguing patents on Bt Cotton Seeds initially as plants patents, thereafter as genes patents and presently as chemicals patents. Monsanto is concealing from the courts that a gene in its chemical structure becomes plant's part and its future production by referring Bt genes as a technology and currently as a chemical product. Monsanto claim for a Bt Cotton seed patent is false because its patent was for a lab method for joining Bt gene to an existing cotton plant.

Now after legal assertion, Monsanto did not have a Bt Cotton patent and it has accumulated royalties from farmers in an illegal way, confining them in debt, and forcing thousands of cotton farmers to suicide. Now Monsanto has to pay.

19.16 IPR AND INDIAN AGRICULTURE

There are lots of debates regarding the consequences of IPR in agriculture. But the fact is that a proper IPR regime cannot protect foreign inventors and domestic players. Some prominent instances of IPR are given below:

19.16.1 Turmeric

In the year 1995, the US Patent Office granted the claim made by the two scientists in the invention was of using turmeric powder at the site of injury by oral intake or tropical applications. But the Council for Scientific and Industrial Research (CSIR) challenged the claim, thereby giving the 32 references from ancient texts showing the previous knowledge on turmeric usage in the form of powder. The US Patent office re-examined the claim, stated that it lacks novelty and hence revoked the patent.

16.2 Neem

The US and European laboratories held more than 40 patents on Neem pesticides. W. R. Grace, a US-based company, was accorded a patent for the usage of Neem in pesticide. Indian scientists were experimenting with it but were unable to challenge the claim as the patent was not earlier applied for the said process. Out of around 80 patents on Neem, accorded to the country, 48 are of Indian origin. Neither any royalty was paid nor these patents have restricted Indians from the usage of Neem.

19.16.3 Cotton

In October 1992, the W. R. Grace-based subsidiary, named as Agracetus Inc., was accorded the patent rights on all the genetically engineered cotton varieties along with the usage of all the techniques in its production. The same was challenged in court and subsequently in the year 1994, the US Patent Office cancelled the claim.

19.16.4 Basmati

RICETEC, in September 1997, obtained a patent regarding the naming of aromatic rice as Basmati, being grown out of India and further advertising the same under its brand name. Moreover, RICETEC had already started selling rice under its brand names such as texmati and kasmati, claiming it as Basmati-type rice and labelling its rice exports. It declared Basmati as a generic term, thus inventing a particular novel grain of Basmati, thereby making possible the generation of high-quality, high-yielding basmati rice globally through the segregation of certain scientific parameters such as the ratio of length-width, starch index, percentage increase at the time of cooking, etc., or else, due to the distinct combination of soil, environment, climate, practices of sowing and genetic variety, genuine Basmati is found in India and Pakistan only. As per RICETEC, the basis of invention such as the certain characteristics of basmati grain and plant and its growing environment aspects for traditional basmati rice are not significant to the supposed product quality. This is considered as the GI issue instead of patents, thereby linking it to the production area of a product such as champagne, which can only be from the France Champagne district and feta cheese from Greece's goat cheese, even though they can be grown anywhere worldwide. The said line of defence can be used by India for its case argument, in spite of not having any law in relation to geographical indication, which can be advantageous for Darjeeling tea and other related products, just like Champagne.

19.17 WORLD INTELLECTUAL PROPERTY ORGANISATION (WIPO)

19.17.1 WIPO Structure

The WIPO is a United Nations self-funding agency serving intellectual property services, information, policy and cooperation. The WIPO, at present has 193 member states, with its main aim/objective for developing a balanced and effective international intellectual property (IP) system that supports creativity/creativeness and innovation for everyone. WIPO's mandate, governing bodies and procedures are set out in the WIPO Convention, which was established in 1967.

- The WIPO helps in realising the advantages of Intellectual Property to different governmental and non-governmental bodies.
- The WIPO sets out a programme on the member states and budget for all the proposed activities, objectives, measures and performances and

reports, on the basis of each year's results in the Program Performance Report.

- WIPO submits biennial reports on financial management and financial statements annually to the Member States Assemblies, formulated as per the International Public Sector Accounting Standards.
- They work closely worldwide, in collaboration with the offices of Intellectual Property, NGOs, IGOs and other public and private stakeholders for delivering the programmes. By providing a stable environment for marketing products protected by intellectual property, it also oils the wheels of international trade. The WIPO works closely with its member states and other constituents to ensure the intellectual property system remains a supple and adaptable tool for prosperity and well-being, crafted to help in the realisation of the full potential of created works for present and future generations.

19.17.2 WIPO's Promotion in the Protection of Intellectual Property

The WIPO functions as a medium for its member states for the establishment of rules and practices in order to safeguard the intellectual property rights, act as a global registration systems for trademarks, industrial designs, a global filing system for patents and appellations of designs. WIPO's members regularly review this system.

Member states and other stakeholders are also determined for improved and better services. The intellectual property protection systems of many countries are very old, as they are not updated. Therefore, a lot of developing countries are in the course of formulating their legal structure related to patent and copyright trademarks and intellectual systems of property. WIPO performs an important role in accommodating these systems for their development with the help of treaty negotiation, technical and legal assistance, various forms of trainings, with the inclusion of the enforcement field in the era of the ever-increasing trade globalisation and rapid transformation in technological advancement.

WIPO performs globally along with its member countries for ensuring better recognition, easy understanding, accessibility and availability of intellectual property information from the grassroots level to the business sector and policymakers.

19.17.3 Funding of WIPO Audience

The WIPO is an autonomous organisation, in which the maximum budget is generated with the help of its global systems of registration and filing utilised by the various countries and member states, besides its services of publications and arbitration and mediation. Afterwards, the member countries donate the remaining funds.

Note: N.B. Indian Patent Act, 2005, Geographical Indications of Goods (Registration and Protection) Act, 1999, and Trademark Act, 1999, are administered by the Department of Indian Policy and Promotion (DIPP) under the Ministry of Commerce and Industry. The Copyright Act, 1957, was administered by the HRD Ministry, but after approval of National Policy, this Act will also be administered under DIPP.

QUESTIONS AND ANSWERS

20.1 TERMINOLOGY

Proxima Centauri It is a red dwarf star. It is very faint, hence can be seen through a telescope. It was discovered in 1915.

Big Bang Theory This is the cosmological theory that states that all the matter and energy in the universe originated from a state of enormous density and temperature that exploded at a finite moment in the past. This theory successfully explains the expansion of the universe.

Cosmic Background Radiation Scientists have detected a faint radio signal; present in space, which they believe, is a faint glow from the Big Bang's superhot fireball.

Black Hole A black hole forms when a large dying star collapses or explodes. When a star has run out of fuel, it cannot stop gravity pulling its gas together, squeezing it tighter, until it forms a black hole. Black hole emits no light. Radio astronomy equipment detects its presence.

Worm Hole A worm hole is a short-lived portal. It joins two black holes in different locations.

Antiparticle This is a subatomic particle that has the same mass as another particle and equal but opposite values of some other properties.

20.2 UNIVERSE, SPACE AND COSMOS

The **universe** is a collection of things in space that are similar to a space-time fabric and have its contents. It includes many components like stars, galaxies and the contents of intergalactic space, planets, moons and minor planets. Our universe is made up of matter and energy that was generated/released by the Big Bang. The size of the entire universe is still unknown.

Space is the part of the universe that is outside of Earth's atmosphere. Earth is described as a part of the universe but by definition, Earth is not a part of space.

Physical **space** is a linear three-dimensional structure, although it has a fourth-dimensional structure, i.e., time, those all together known as **space-time.** The **cosmos** is a complex and orderly system in universe.

20.2.1 Origin and Expansion of the Universe

According to most of the astronomers; 'the origin of universe' involved a gigantic explosion of matter and energy, about 13.6 billion years ago, called the 'Big Bang' theory. **'Big'** means large matters and **'Bang'** means strike violently. Now striking of big matters is 'Big Bang'. In 1920, Edwin Hubble provided evidence that the universe is expanding, i.e., also called 'Expanding Universe Hypothesis'.

Two discoveries have helped in promoting the 'Big Bang' theory and expansion of the universe concept: First, is a measured redshift in the light radiated from distant stars. This property of starlight is similar to the lowering in pitch of a departing train whistle, known as Doppler's effect.

Second is the presence of weak microwave radiations throughout the space. This background radiation detected by Arno Penzias and Robert Wilson is found to have a characteristic temperature just three degrees above absolute zero.

Fragments of matter and the space itself have been expanding outward like a display of fireworks. Stars, galaxies and planets gradually formed from these fragments in a purely mechanistic fashion. As time passed, galaxies shifted more and more apart. Distance between them was found to be increasing, so it is believed that the universe is expanding.

20.3 COSMIC INFLATION THEORY

In the year 1981, the Theory of Cosmic Inflation was given by Alan Guth. As per the theory, ripples were sent **(primordial gravitational waves), which are responsible for the polarisation of the universe, thereby resulting in the widening of cosmic space and compressing** due to a swift universe expansion phase, immediately after the Big Bang, occurring at a pace faster than the light.

20.4 RED SHIFT AND BLUE SHIFT

The light, having unique spectral features coming from distant stars and galaxies, when examined under VIBGYOR, tilted towards the spectrum's red end **(red shift)** has the largest wavelength, thereby pointing towards the movement of galaxies away from us. The similar phenomena, which points towards the distant objects moving nearer to the observer is termed as the **blue shift.**

20.5 COSMIC MICROWAVE BACKGROUND RADIATIONS

These are the thermal radiations, which remained after the Big Bang. The European Space Agency's Planck spacecraft effectively prepared a map of the cosmic microwave radiation in the sky, which pictured the oldest light in our universe, termed as the cosmic microwave background (CMB). In each direction, it is filling the universe and its existence in itself is an evidence of Big Bang theory and accordingly, an expanding universe.

There is an in-depth understanding of composition of the universe with the help of the cosmic microwave background radiation. As per the CMB observation, the universe is mostly made up of dark energy, which, being a mystifying force, drives the expansion of the universe and further, the dark matter interacts with the remaining universe merely with the help of its gravity.

20.6 MISSING LINKS IN UNIVERSE

Mass, time and initial expansions of universe are some of the desired missing links in the 'Big Bang' theory.

Concept of missing mass If an expanding universe were to consist of sufficient material and unlimited time, gravity would eventually stop the outward motion and pull everything back together again into a cataclysmic fireball.

Time is a missing link Many observations indicate a recent creation of universe; only thousands of years ago instead of the assumed billions of years of history. There is also a missing explanation for the initial formation of stars. The calculations done by James Clerk Maxwell show that a gas cloud in space will simply not collapse itself into a star. Instead, the gas dissipates outward due to thermal pressure, in accordance with the 'Second Law of Thermodynamics', the universal tendency towards disorder.

Confirmations In late 1940s, George Gamow suggested that the initial explosion might have left some traces that are still observable. He reckoned that the universe, so hot and dense, would have emitted a lot of light. In 1965, Arno Penzias and Robert Wilson discovered that the static continued, no matter where they pointed the antenna. When they measured the radiation, they found a value close to that expected for cosmic background radiation – 2.7 Kelvin (close to absolute zero). This confirms the 'Big Bang' theory and they won the Noble prize in 1978.

Does the theory explain everything?

It has passed through various stages, all of which can be considered as cosmological theories: the flat Earth, the geocentric mode, heliocentricity, the big bang. Each model explains what was known at the time and what the measures could confirm. It cannot be said that those theories were wrong; perhaps, they were incomplete.

20.7 MATTER AND ANTIMATTER

Concept of zero In the beginning of universe, matter and antimatter, both were parallelly formed during the incidence of Big Bang (from a highly dense body). At the time of Big Bang, the temperature was very high. [As zero is the sum of (+1) + (-1) = 0; Here, +1 is matter and -1 is antimatter]. Matter and antimatter have equal mass but opposite charge; for example, electron (-e) and positron (+e), both have same mass but opposite charges. If matter and antimatter are created and destroyed together, the universe should contain nothing but left-over energy.

Spontaneous transformations have been observed by researchers, between particles and their antiparticles, occurring millions of times per second before they decay. Some unknown entity intervening in this process in the early universe could have caused these 'oscillating' particles to decay matter more often than they decayed antimatter.

Corresponding to most kinds of particles, there is an associated **antiparticle with the same mass and opposite electric charge.** For example, the antiparticle of the electron is the positively charged anti-electron or positron, which is produced naturally in certain types of radioactive decay. A hydrogen atom is composed of a proton (a positively charged particle) and a much less massive electron (a negatively charged particle). A positron and an antiproton can form an anti-hydrogen atom (antimatter) in the same way that an electron and a proton form a normal matter hydrogen atom (matter). **When matter and antimatter come into contact, they annihilate each other and produce vast amounts of energy.**

For reasons unknown to physicists, **very little antimatter exists in our universe.** Theoretically, when the universe was formed, there should have been equal amounts of matter and antimatter; however, our universe consists primarily of matter. There is a considerable speculation in theoretical physics as to why the observable universe is apparently almost entirely made up of matter. But at this time, this apparent asymmetry of matter and antimatter in the visible universe is one of the greatest unsolved mysteries in physics. There is also research into whether there exists other places that are almost entirely made of antimatter instead, and what might be possible if antimatter could be harnessed.

If antimatter can be produced artificially and controlled, the matter–antimatter reaction can be used to provide vast amounts of energy and can propel the spaceships of the future. But as of now, little is understood about antimatter. It is expensive to produce antimatter by current technology. **Tiny amounts of antimatter can be produced in particle accelerators such as the Large Hadron Collider.** It takes far more energy to produce antimatter today than one can get from the annihilation reactions of this antimatter. Also, the antimatter so produced cannot be controlled and made use of.

(Refer **Infographic – Matter & Antimatter**)

Brookhaven National Laboratory – Brookhaven National Laboratory is a **United States Department of Energy National Laboratory** located in **Upton, New York.** Mission of Brookhaven National Laboratory is to perform **advanced fundamental research in nuclear and particle physics** to gain **a deeper understanding of matter, energy, space and time; apply photon science and nanomaterial research to energy challenges of critical importance to the nation; and perform cross-disciplinary research on climate change, sustainable energy and Earth's ecosystems.** Many Indian scientists are also working here to find some results and unravel the mysteries of the universe.

20.8 DARK MATTER AND DARK ENERGY

Dark Energy and Dark Matter

Astronomical observations suggest that **a significant part of the universe is made up of dark matter which interacts with the rest of the universe only through the gravitational pull.** Many large lab experiments have tried to detect elementary particles that could be candidates for dark matter. However, such dark matter particles have not been detected until now.

Assessing Dark Matter

The researchers use the non-observation of the lensing signatures to assess what fraction of the dark matter could be made of black holes. **Gravitational lensing is useful to cosmologists because it is directly sensitive to the amount and distribution of dark matter.**

Dark Energy

- More is unknown than is known. We know how much dark energy there is because we know how it affects the universe's expansion. Other than that, it is a complete mystery. But it is an important mystery. It makes up about 68% of the universe.
- **Dark Energy is a hypothetical form of energy that exerts a negative, repulsive pressure, behaving like the opposite of gravity.**
- **It is causing the rate of expansion of our universe to accelerate over time, rather than to slow down.** That's contrary to what one might expect from a universe that began in a Big Bang.

Difference between Dark Energy and Dark Matter

- Everything we see – the planets, moons, massive galaxies – makes up less than 5% of the universe. **About 27% is dark matter and 68% is dark energy.**
- While **dark matter attracts and holds galaxies together, dark energy repels and causes the expansion of our universe.**
- The existence of dark matter was suggested as early as the 1920s, while dark energy was not discovered until 1998.

XENON1T Experiment

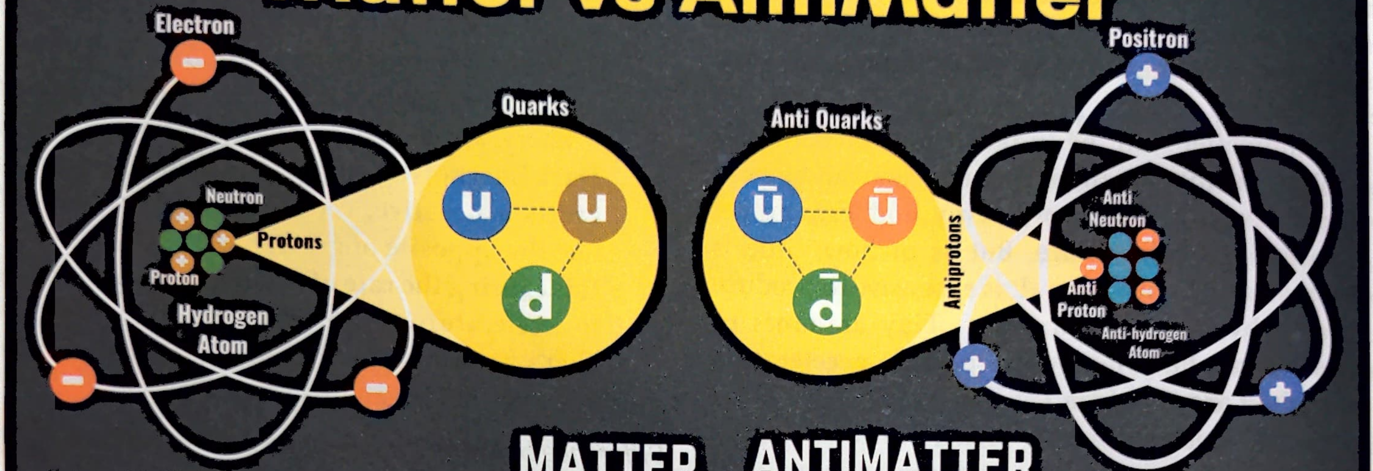
- It is **the world's most sensitive dark matter experiment** and was operated deep underground at the **INFN Laboratori Nazionali del Gran Sasso** in **Italy**.
- It uses the **dual-phase (liquid/gas) xenon technique** and is located underground at the Laboratori Nazionali del Gran Sasso of INFN, Italy.

20.9 GALAXY

There are millions of stars in the universe, together forming a group called galaxy. Stars are not uniformly distributed in the universe. Galaxy is a gravitationally bound system of stars, dust, interstellar gas and dark matter.

Each galaxy may contain as many as hundred million stars. There are millions of galaxies in the universe. Our Sun belongs to a galaxy called the 'Milky Way Galaxy'. It is believed that the Earth's own galaxy (Milky Way) alone contains as many as 1,00,000 million stars.

Matter vs AntiMatter



MATTER

Matter is composed of particles known as fermions, such as protons, neutrons, and electrons. These particles have a positive or negative charge and contribute to the structure of atoms.

Matter particles typically have a positive, negative, or neutral electric charge. For example, protons carry a positive charge, electrons carry a negative charge, and neutrons have no electric charge.

ANTIMATTER

Antimatter consists of antiparticles, which have the same mass as their corresponding matter particles but possess opposite charges.

Antimatter particles, however, have charges opposite to their matter counterparts. Antiprotons have a negative charge, positrons (antielectrons) have a positive charge, and antineutrons have no electric charge.

When matter and antimatter particles come into contact, they can undergo a process called annihilation. Annihilation occurs when a particle collides with its corresponding antiparticle, resulting in the conversion of their mass into energy. This process releases an enormous amount of energy in the form of gamma rays or other particles.

The interactions between matter and antimatter are governed by certain conservation laws. For example, the law of conservation of electric charge states that the total electric charge must remain constant in a particle interaction. In the annihilation process, if a particle and its antiparticle have opposite electric charges, their combined electric charge is zero, satisfying the conservation of charge.

In our observable universe, matter is much more abundant than antimatter. This is known as the matter-antimatter asymmetry problem, which remains an open question in physics. The reasons for this imbalance and why antimatter is rare compared to matter are still being explored.

COMET

A comet is a celestial object made up of a solid core called the nucleus, surrounded by a glowing cloud of gas and dust called the coma. When a comet approaches the Sun, the heat causes the nucleus to vaporize, creating a coma and forming tails composed of dust and ionized gas. Comets originate from the Kuiper Belt and the Oort Cloud and provide valuable information about the early solar system.

ASTEROID

An asteroid is a rocky or metallic object that orbits the Sun, found primarily in the asteroid belt between Mars and Jupiter. They vary in size, shape, and composition, and are remnants from the early solar system. Some asteroids come close to Earth, and studying them provides insights into our solar system's history and potential resources.

METEORITE

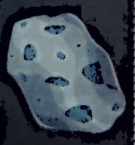
A meteorite is a solid object from space that survives its journey through Earth's atmosphere and lands on the surface. It provides valuable information about the composition and history of asteroids and other celestial bodies. Meteorites come in different types, such as stony, iron, and stony-iron, and they help scientists study the early solar system.

METEOR

A meteor is a small object from space that enters Earth's atmosphere, creating a bright streak of light due to friction with the air. It is commonly known as a shooting star or falling star. Meteors are fragments of comets or asteroids that vaporize as they pass through the atmosphere. Meteor showers occur when Earth intersects with the debris left by comets, leading to a higher concentration of meteors.

METEOROID

A meteoroid is a small object in space, ranging from dust-sized particles to several meters in diameter. It originates from comets, asteroids, or other celestial bodies. When a meteoroid enters Earth's atmosphere, it heats up and vaporizes, creating a visible streak of light known as a meteor or shooting star. Some meteoroids survive the atmospheric entry and become meteorites when they land on Earth's surface. Meteoroids play a role in meteor showers and provide insights into the composition of celestial bodies. If a meteoroid survives and lands on Earth, it is called a meteorite.



FIREBALL

A fireball is an exceptionally bright and luminous meteor that appears as a large and intense ball of light streaking across the sky. It is caused by larger and more massive meteoroids entering Earth's atmosphere at high speeds. Fireballs are brighter, last longer, and can produce sonic booms. Some fireballs survive and may yield meteorite fragments when they land on Earth.

These stars are so far away from us that they cannot be distinguished individually and hence, appear as a white band.

The galaxies are calculated in thousands of light years spreading over large distances and their diameters range from 80,000 to 1,50,000 light years. A galaxy is formed by the hydrogen gas amassing in the form of a very large cloud termed as 'Nebula'. In due course, a growing nebula expands into a localised gas mass, which continues growing into even denser gaseous bodies. There are three main types of galaxies, i.e., elliptical, spiral and irregular.

Collision of gases and dust creates new stars within galaxies. Many galaxies are found in galaxy clusters, with thousands of members. Our galaxy, the Milky Way (Akashganga) belongs to a cluster of about thirty galaxies called the 'Local Group'. It takes light 1,00,000 years to pass from one edge of the Milky Way to the other. Light from the centre of the Milky Way takes 25,000 years to reach us on the Earth.

In a few billion years, the Milky Way and Andromeda galaxies will likely collide and form a combined galaxy. Edwin Powell Hubble studied galaxies and devised a classification system for galaxies based on their shapes.

SARASWATI (SUPERCLUSTER OF GALAXIES)

A team of Indian astronomers identified a previously unknown, extremely large supercluster of galaxies located in the direction of constellation, Pisces. The supercluster of forty-three galaxies, which they named **'Saraswati'**, is one of the largest known structures in the nearby universe, and is four billion light years away from us and may contain the mass equivalent of over twenty million billion Suns. The Saraswati supercluster, for instance, extends over a scale of 600 million light years.

A team of Indian astronomers from **Inter-University Centre for Astronomy and Astrophysics (IUCAA)**, Pune, Indian Institute of Science Education and Research (IISER), Pune National Institute of Technology (NIT), Jamshedpur and Newman College (Thodapuzha) identified a massive supermega river of galaxies. The new discovery has been named Saraswati, which in Sanskrit literally means 'ever-flowing stream with many pools'. The discovery is forcing the astronomers to rethink about the early evolution of the universe and provides vital clues about the mysterious dark matter and dark energy.

20.10 NEBULAE

Stars are born in an enormous cloud of interstellar dust and hydrogen gas called a nebula. Nebulae represent the building blocks for stars, galaxies and planets in the universe. New stars are being born in one of the nebulae. Other nebulae are the remains of dead or dying stars. Emission nebulae are hot, discrete clouds of primarily ionised hydrogen that glow with their own light. Reflection nebulae emit a bluish glow by reflecting the light of nearby stars.

Nebulae may be bright or dark. The bright nebulae shine. Some shine by reflecting the light of nearby stars. Others shine because the gases in them start glowing on being heated by nearby stars. The dark nebulae do not shine. They block light and look like dark patches when seen against a brighter region of space. Dark nebulae are also known as absorption nebulae.

Nebulae form when stars die. When the stars are near their end, their outer layers will heat, swell and eventually blow off. The hot, dead core will create a glowing nebula, which will in turn become a nursery for new stars. The shapes and spectral characteristics of planetary nebulae are unique and visible from a great distance. Some of the well-known nebulae are horsehead, lagoon, eagle and cat's eye, which have acquired these names inspired by their shapes.

Nebulae are major contributors to the chemical enrichment of galaxies, especially nitrogen and carbon. They also act as multi-wavelength laboratories for understanding atomic, molecular, dust and plasma processes in different astrophysical environments. Horsehead nebula, one of the dark nebulas, is situated in the Orion constellation in space.

20.11 LIFE CYCLE OF STARS

Refer **Infographic – Life Cycle of a Star.**

20.12 PLANETS

The word 'PLANET' is derived from a Greek word **Planetai,** meaning **wanderer.** Planets are so named because they revolve around the Sun. Planets do not have their own light, as they are made-up of solid material and gases. They shine with the light reflected from the Sun. Planets are developed by the gravitational force present in the stars. The stars are localised gas lumps inside a nebula. The force of gravity inside the

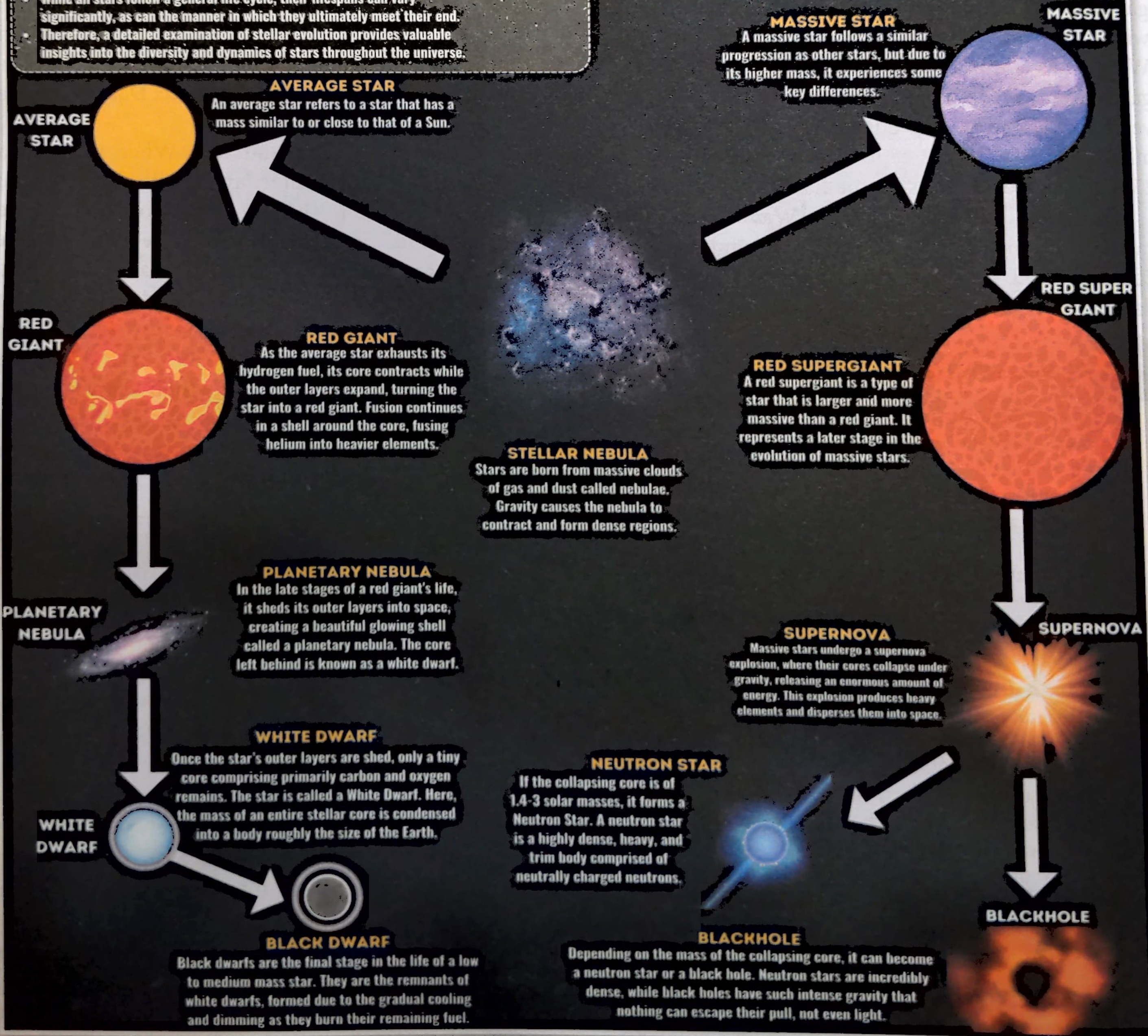
LIFECYCLE OF A STAR

WHAT IS A STAR?

- Star can be described as enormous sphere composed of intensely hot and luminous gases, predominantly hydrogen and helium, which are held together by the force of gravity.
- Notable examples of stars include Pollux, Sirius, Vega, Polaris, and our very own Sun.
- These celestial objects serve as the fundamental building blocks of galaxies and act as the primary source of heavier elements in the universe.
- Therefore, studying their age, composition, and distribution is crucial for gaining insights into the workings of the cosmos.
- To gain a comprehensive understanding of the universe, it is imperative to delve into the intricate details of stellar evolution.
- Stellar evolution refers to the process by which a star undergoes changes over time, analogous to the life cycle of a human being.
- While all stars follow a general life cycle, their lifespans can vary significantly, as can the manner in which they ultimately meet their end.
- Therefore, a detailed examination of stellar evolution provides valuable insights into the diversity and dynamics of stars throughout the universe.

WHAT DETERMINES THE LIFE CYCLE OF A STAR?

- The life cycle of a star is influenced by its mass, which, in turn, depends on the amount of material present in the nebula from which it originates.
- A star with a greater mass has a comparatively shorter lifespan. This is primarily due to the fact that massive stars have higher core temperatures, leading to a faster consumption of their hydrogen fuel supply. On the other hand, stars of different types tend to burn for longer durations, but they also tend to have lower temperatures.



AVERAGE STAR
An average star refers to a star that has a mass similar to or close to that of a Sun.

RED GIANT
As the average star exhausts its hydrogen fuel, its core contracts while the outer layers expand, turning the star into a red giant. Fusion continues in a shell around the core, fusing helium into heavier elements.

PLANETARY NEBULA
In the late stages of a red giant's life, it sheds its outer layers into space, creating a beautiful glowing shell called a planetary nebula. The core left behind is known as a white dwarf.

WHITE DWARF
Once the star's outer layers are shed, only a tiny core comprising primarily carbon and oxygen remains. The star is called a White Dwarf. Here, the mass of an entire stellar core is condensed into a body roughly the size of the Earth.

BLACK DWARF
Black dwarfs are the final stage in the life of a low to medium mass star. They are the remnants of white dwarfs, formed due to the gradual cooling and dimming as they burn their remaining fuel.

STELLAR NEBULA
Stars are born from massive clouds of gas and dust called nebulae. Gravity causes the nebula to contract and form dense regions.

MASSIVE STAR
A massive star follows a similar progression as other stars, but due to its higher mass, it experiences some key differences.

RED SUPERGIANT
A red supergiant is a type of star that is larger and more massive than a red giant. It represents a later stage in the evolution of massive stars.

SUPERNOVA
Massive stars undergo a supernova explosion, where their cores collapse under gravity, releasing an enormous amount of energy. This explosion produces heavy elements and disperses them into space.

NEUTRON STAR
If the collapsing core is of 1.4-3 solar masses, it forms a Neutron Star. A neutron star is a highly dense, heavy, and trim body comprised of neutrally charged neutrons.

BLACKHOLE
Depending on the mass of the collapsing core, it can become a neutron star or a black hole. Neutron stars are incredibly dense, while black holes have such intense gravity that nothing can escape their pull, not even light.

lumps leads to the gas cloud core formation, which results in the creation of a huge rotating gas and dust disc around its core.

The gas cloud gets condensed and develops into small-rounded objects known as **Planetesimals.** They are a large number of smaller bodies held together by gravitational attraction. At last, these huge tiny planetesimals accumulate and result in the formation of a fewer large bodies in the form of planets. The planets have two types of movements, viz., rotation and revolution. Each planet has its own axis about which it rotates or spins. Two planets, Venus and Uranus, rotate from East to West. All other planets rotate in the anticlockwise direction, that is from West to East. The planets also revolve around the Sun in fixed paths. The path of revolution of each planet is egg-shaped or elliptical and is known as its orbit.

Each planet takes a different time period to complete one rotation about its axis and one revolution around the Sun. The formation of all the planets occurred in the same period, around 4.6 billion years ago. All the planets are spherical in shape. According to IAU (International Astronomical Union), a planet is a celestial body that (i) orbits a star, (ii) has acquired a roughly round shape by its own gravity, (iii) contains enough mass that its gravitational field has cleared its orbit of debris.

Classification of Planets

Planets can be classified into two types, according to the position of their orbits with respect to the Earth's orbit.

1. **Inferior planets:** Their orbits lie within the orbit of the Earth, e.g., Mercury, Venus.
2. **Superior planets:** Their orbits lie outside the orbit of the Earth, e.g., Jupiter, Saturn, Uranus and Neptune.

Planets are also classified on the basis of their distance from the Sun:

1. **Inner planets:** They are closer to the Sun.
   - They are small in size and have relatively high densities.
   - Gravity is low, hence, they could cannot hold the escaping gases.
   - They are positioned in between the Sun and the belt of asteroids.
   - They are made up of rocks and metals and are also called terrestrial planets, means Earth-like.
   - The formation of terrestrial planets occurred in the close surroundings of the parent star.
   - Near to the Sun, the solar winds are most intense, thereby, blowing off huge amounts of gases and dust.
   - They take a short time to complete one revolution, e.g., Mercury, Venus, Earth and Mars.
2. **Outer planets:** They are far away from the Sun.
   - They are very large in size and have relatively low densities.
   - Gravity is comparatively high, hence, can hold the escape gases.
   - They lie outside the belt of asteroids.
   - They are made up of gases and are also called gas giants.
   - They are also known as Jovian planets, means Jupiter-like. Jovian planets are formed at quite a distant location.
   - Solar winds are not intense to cause removal of gases from the Jovian planets.
   - They take a long time to complete one revolution, e.g., Jupiter, Saturn, Uranus, Neptune.

In descending order of their size, the planets are Jupiter, Saturn, Uranus, Neptune, Earth, Venus, Mars and Mercury.

20.13 DWARF PLANETS

The term 'Dwarf Planet' was adopted in 2006 due to the discovery of objects beyond the orbit of Neptune; that were comparable in size to Pluto. According to the definition adopted by IAU (International Astronomical Union), a **dwarf planet should follow various criteria**:

- It should be in orbit around the Sun.
- It should have sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round shape).
- It does not have a clear neighbourhood around its orbit.
- It has no satellite.
- It has a weak gravitational pull.
- It has debris within its orbit.

There are currently five dwarf planets, namely: **Pluto, Eris, Makemake, Haumea, Ceres.** These are all present in the Kuiper belt (**Figure 20.1**).

It is possible that there are another forty known objects in the solar system that could be rightly classified as dwarf planets.

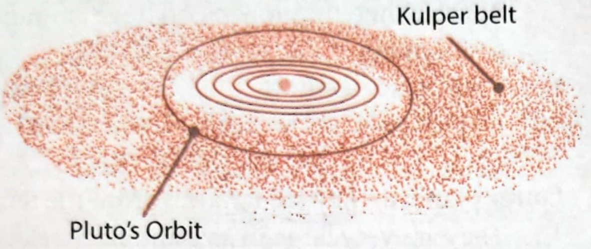


Figure 20.1
Position of Pluto in Kuiper belt

20.14 EXOPLANETS

Exoplanets, by definition, are planets beyond our solar system. Scientists also call them extra-solar planets.

- With the launch of Kepler mission in 2009, more than 2,300 of the exoplanets were confirmed.

20.15 GOLDILOCKS ZONE (OR HABITABLE ZONE)

On the basis of Kepler space mission data, astronomers reported that there are about forty billion Earth-sized planets orbiting in the 'habitable zones' or 'life zones' of Sun-like stars and red dwarf stars within the Milky Way Galaxy. Terrestrial planets are also more likely to lie in the Goldilocks Zone. Goldilocks region is an area of space in which a planet is at just the right distance from its home star so that its surface is neither too hot nor too cold. If we observe Venus, it has a lot of greenhouse effect but Mars exists as a frozen, arid world. In between both these planets, the conditions are just right so that liquid water remains on the surface of the planet without freezing or evaporating into the space. Hence, the possibility of life is maximum in this zone. Now, the search is on to find another planet in the Goldilocks zone of another solar system.

20.16 SOLAR SYSTEM

Sun and its family are together called as the solar system.

20.16.1 Sun

It is the closest star to our planet. Like all stars, it is a ball of hydrogen gas that radiates heat and light, fed by constant explosions. It generates power by nuclear fusion (smaller nuclei combined to form larger nuclei and produce energy).

- Sun converts nearly four million tonnes of matter into energy every second.
- Sun was born five billion years (approximately) ago. It is so huge that it will continue to burn for another five billion years.
- It is composed of about seventy-four per cent hydrogen and twenty-five per cent helium, with traces of iron, carbon, calcium and sodium.
- The Sun is the centre of the solar system. Sun is only around eight light minutes away from the Earth. Due to the reflection of sunlight, we are able to see other things. Sun is the source of energy for our planet.
- The Sun accounts for ninety-nine per cent of the total matter in our solar system.
- Like other planets in the solar system, the Sun spins on its axis.
- The Sun takes up to 250 million years to complete one revolution around the Milky Way.
- With the help of its different layers such as photosphere, chromosphere and corona, Sun can be easily described. Photosphere is the visible surface of the Sun, from which the emitted sunlight reaches the Earth. Chromosphere is the layer above photosphere and below the corona. Corona is the outermost region of the Sun's atmosphere (consisting of plasma or hot ionised gases), which is visible as a white halo during solar eclipse. The heat of corona is caused by magnetic field and undergoes constant changes.
- Solar activity occurs in the outer layers when a strong magnetic field breaks through the photosphere and emits intense radiation.

20.16.1.1 Solar Wind

The Sun emits a stream of invisible particles called the solar wind. It creates shimmering lights when passed through the polar regions of the Earth.

(i) It consists mostly protons and electrons with tiny amounts of silicon, sulphur, calcium, chromium, nickel, argon and neon.
(ii) Solar wind produces auroras (stunning light at polar regions) and also makes the tails of comets that point away from the Sun.

(iii) Heavy solar winds can disrupt telecommunication on the Earth.

20.16.1.2 Solar Tsunami

A solar tsunami is a powerful shockwave on the Sun's surface, triggered by explosions in its atmosphere that result in large amounts of superhot plasma, containing electrically charged particles, being expelled into space. The solar tsunami is technically referred to as a Magnetohydrodynamical Wave (MHD wave), as the explosions that causes it result from release of magnetic energy in the Sun's atmosphere. It is also called as a More-ton wave. The release of the superhot plasma is technically referred to as a 'Coronal Mass Ejection' (CME).

Solar tsunamis were discovered in 1997 by the Solar and Heliospheric Observatory (SOHO) spacecraft of the NASA, USA. The SOHO confirmed their reality in February 2009, when sunspot 11012 unexpectedly erupted, hurling a huge coronal mass ejection into space and sending a massive shockwave across the Sun's surface. This shockwave came to be known as a solar tsunami in general and MHD wave in scientific parlance.

20.16.1.3 Solar Flares

Solar flares are sudden eruptions on the surface of the Sun. They spurt fiery gases beyond the Sun's corona and into the space. Solar flares release energy of the order of billions of tonnes, at more than 600 miles per second into the space. Solar flares last only for a few minutes. The charged particles of solar flares sometimes extend to the Earth's magnetic field, which can cause auroras, geomagnetic storms and disruption to satellite communication.

20.16.1.4 Sunspot

Sunspots are the cooler and darker areas (cooler as compared to other parts of the Sun's surface) where the field breaks through the photosphere. The regions which appear to be darker on the surface of the Sun are termed as Sun spots, being 1500K cooler than surrounding photosphere. As the sunspots are darker relatively, thus, a sunspot removed from the bright background of the Sun would glow quite brightly. The frequency with which sunspots appear and their location on the Sun's surface changes over time in a pattern is called the sunspot cycle.

Cause Behind the Sunspots

Sunspots are temporary phenomena on the Sun's photosphere, thereby, appearing clearly as dark spots in comparison to the surrounding regions. The extreme magnetic action inhibiting convection by an effect analogous to the eddy current brake, leading to the formation of reduced surface temperature is the major reason for its occurrence. They also have two poles similar to that of magnets. Even though the temperature of Sun spots is nearly 3000–4500 K (2727–4227°C), their contrast with the temperature of surrounding material at nearly 5,780 K makes them clearly visible as dark spots, as the heated black body's luminous intensity is a function of fourth power of the temperature.

Basic Features of Sunspots

- The diameters of largest experienced sunspots is nearly 50,000 kilometres, making them big enough to be spotted with the naked eye.
- Usually, the sunspots are spotted in groups with nearly hundred in a group, despite the fact that sunspot groups greater than ten are relatively rare. In order to measure the sunspots, there are well-established methods.
- Sunspots remain for hours to months, and move around the Sun's surface through its rotation.
- A typical sunspot consists of a dark, central region called the umbra and somewhat lighter surrounding region called the penumbra.

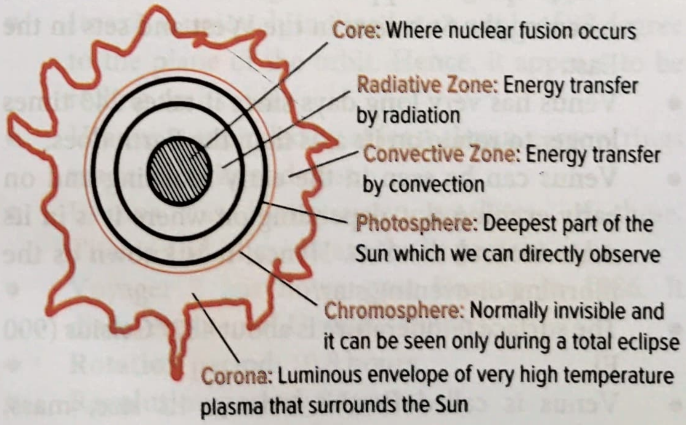

Core: Where nuclear fusion occurs
Radiative Zone: Energy transfer by radiation
Convective Zone: Energy transfer by convection
Photosphere: Deepest part of the Sun which we can directly observe
Chromosphere: Normally invisible and it can be seen only during a total eclipse
Corona: Luminous envelope of very high temperature plasma that surrounds the Sun

Figure 20.2
Sun Structure

20.16.2 Different Planets

20.16.2.1 Mercury

- Smallest planet and also closest to the Sun.
- **Revolution period:** Eighty-eight days. It has the fastest revolution in the solar system. **Rotation period** is 58.65 days.
- Revolves on its axis so slowly that one Mercurian day lasts fifty-nine Earth days.
- The surface of Mercury has thousands of craters.
- It has no atmosphere, so does not trap the Sun's heat.
- It has a large iron core, suggesting that it lost most of its surface in an ancient collision.
- It experiences great extremes of temperature: hot days and freezing nights.
- Second hottest planet after Venus.
- Mercury has no satellite.

20.16.2.2 Venus

- Named after the Roman goddess of love and beauty.
- After the Sun and the Moon, this planet is the brightest object in the sky.
- The thick atmosphere of carbon dioxide causes a greenhouse effect, resulting in a surface temperature of more than 450 Celsius. Hence, Venus is the hottest planet.
- **Rotation period:** 257 days; and **revolution period:** 224.7 days.
- Highest volcano on Venus: Maat Mons.
- Venus spins in opposite direction to the Earth, meaning the Sun rises in the West and sets in the East.
- Venus has very long days since it takes 243 times longer to rotate on its axis than the Earth does.
- Venus can be seen in the early morning and on early evening sky, depending on where it is in its orbit around the Sun. Hence, it is known as the morning or evening star.
- The surface temperature is about 482° Celsius (900 F).
- Venus is called Earth's twin as its size, mass, density are similar to that of Earth.
- Venus has no satellite.

20.16.2.3 Earth

- Fifth largest planet and third nearest to the Sun.
- Earth has a unique blue and white appearance because more than seventy per cent of its surface is covered with water and its atmosphere is filled with clouds rich in oxygen.
- It is spherical in shape, slightly flattened at the poles and bulging at the equator. This shape is described as a geoid.
- It is the only planet in the solar system where life is known to exist.
- Earth has three distinct features, which makes life possible here: (i) moderate temperature, (ii) suitable atmosphere, (iii) presence of water.
- Earth has one natural satellite: the moon.
- Earth does not produce any light. It reflects the Sun's light.
- **Rotation period:** 23 hours 56 minutes 40.91 seconds
- **Revolution period:** 365 days.

MOON

Moon is the natural satellite of Earth. Different types of features of moon have been identified in the recent past.

Blue moon When two full moons appear in the same calendar month, the second is termed as 'blue moon'. First full moon occurred on 01 January 2018. On 31 January 2018, a rare blue moon event was experienced on large parts of the globe. It was a rare moment, as a blue moon, a supermoon and a total lunar eclipse fell on the same day after more than 150 years.

Super moon It occurs when the full moon is at the closest point of its orbit to the Earth, which is also called the perigee. The moon appears thirty per cent brighter and fourteen per cent bigger than the apogee full moon.

Blood moon The Moon turns into red colour during the height of the eclipse, as some light does reach it even though the Moon is in the shadow of the Earth. Fine particles in the atmosphere scatter (Rayleigh scattering) the blue component of solar spectrum, and what reaches us is the longer wavelength red light.

A lunar eclipse happens whenever the moon passes through the Earth's shadow, also known as its umbra.

20.16.2.4 Mars

- It has been named after the Roman god of war.
- Mars has a reddish appearance because of high iron content in soil, and hence, called as red planet.
- The planet experiences strong winds that create immense dust storms.
- Signs of past tectonic activities are visible in Mars. Four huge craters can be clearly seen. The largest of them is 536 kilometres in diameter.
- Tallest volcano found in Mars: Olympus Mons.
- Mars has two huge polar high caps.
- Light clouds, either of water vapour or of carbon dioxide are visible in the Martian sky.
- Its valles marineris canyon stretches some 2500 miles.
- Surface temperature on Mars is too low for liquid water to exist and Mars has no rivers, seas or oceans.
- Mars has two satellites: (i) Deimos (terror in Greek) (ii) Phobos (fear in Greek).
- **Rotation period:** 24.6 hours and revolution period: 687 days.

20.16.2.5 Jupiter

- Largest planet in the solar system and after Venus, it is the brightest.
- Named after the Roman King of the Gods.
- It is a gas giant, made up mainly of hydrogen.
- It is not entirely round, but a bit flat at its pole.
- Yellowish in appearance.
- On its surface is the 'great red spot', a big red-coloured patch that is three times the size of Earth.
- This planet is surrounded by a mass of hydrogen, helium, ammonia and methane.
- It has faint rings around it, which are a mixture of different gases.
- Despite its size, Jupiter spins faster than any other planet. In fact, one rotation takes just under ten seconds.
- Jupiter has many satellites, sixty-four of which have been discovered till date. Of these, Ganymede (solar systems' largest moon), callisto, Io and Europa are the large ones.
- The Galileo spacecraft reached Jupiter in 1995 to probe Jupiter's atmosphere. It ended its mission in 2003.
- **Rotation period:** 9.8 hours (fastest rotation in the solar system).
- **Revolution period:** 12 years.

20.16.2.6 Saturn

- Named after the father of Jupiter.
- Second largest planet in our solar system.
- It is the only planet whose rings are visible to us because of their large area. The rings are made up of ice, dust and rocks. Ice in Saturn's rings reflects light. This makes them clearly visible.
- Its atmosphere mostly consists of hydrogen and helium.
- Saturn has sixty-two known satellites, of which Titan is the largest.
- Saturn has such a low density that it would float like a cork if dropped into water.
- In 1997, the Cassini spacecraft blasted off for Saturn, with a space probe named Huygens on board. Cassini went into orbit around Saturn in June 2004 and Huygens was dropped on to its largest moon, Titan, in January 2005.
- **Rotation period:** 10.3 hours.
- **Revolution period:** 29 years.

20.16.2.7 Uranus

- Named after the Roman God of the sky.
- This was the first planet to be discovered using a telescope, by astronomer Willium Harschel in 1781.
- It has a thick atmosphere consisting mainly of methane, which gives it a bluish-green appearance.
- Its axis is uniquely inclined at an angle of 98 degree to the plane of the orbit. Hence, it appears to be rolling on its side.
- Uranus is encircled by at least eleven narrow rings made of rocks and dust.
- Uranus has twenty-seven satellites; of these, Titania and Miranda are the important ones.
- Voyager 2 has flown past Uranus in 1986. It discovered ten of Uranus's moons.
- **Rotation period:** 10.8 hours.
- **Revolution period:** 84 years.
- Each of the poles of Uranus experience forty-two years of winter, followed by forty-two years of summer. For twenty-one of those years, they are each in continual darkness or light.

20.16.2.8 Neptune

- Discovered by the astronomer Johann Galle in 1846.
- It is bluish in colour. Its blueness comes from methane in its atmosphere.
- Neptune has a few dark spots, the largest being the 'Great Dark Spot', which in fact is a huge storm.
- It has a system of four faint rings around it, made up of dust particles.
- **Rotation period:** 15.7 days.
- **Revolution period:** 164.8 Earth years.
- Named after the Roman god of sea.
- Neptune is very similar to Uranus. Hence, is known as Twin of Uranus.
- It is a very cold planet due to the large distance from Sun.
- Voyager 2 has flown past Neptune in 1989. It discovered six of Neptune's moons.
- It has thirteen satellites.
- First planet found by mathematical prediction rather than by empirical observation.

20.17 MAGNETIC NORTH POLE DRIFTING FAST TOWARDS RUSSIA

'The magnetic North pole is drifting fast from the Canadian Arctic and towards Russia' has been published in many news reports.

Earth's Magnetism

- The Earth's magnetism originates in its outer core, a more than 2,000-km layer of liquid iron and some other metals like nickel that surround the central core, or the innermost part.
- Due to Earth's rotation, liquid iron is in constant motion and this motion produces a magnetic field.

What's the Issue Now?

- Currently, the magnetic North Pole is located somewhere over northern Canada, a fact discovered in 1831 by Sir James Clark Ross. The magnetic North Pole has been moving across the Canadian Arctic towards Russia, and has moved hundreds of miles over the last several decades. This phenomenon is known as the Polar Shift Theory.
- Scientists have now understood that the speed of this movement has speedily increased, quite significantly, from about 14–15 km per year till the 1990s to about 55 km per year in the last few years. This has led to updating of World Magnetic Model (WMM) that tracks this movement. It was a year ahead of schedule.

Why it is Moving Faster?

- Scientists do not have full clarity on the matter. The movement of liquid iron and other metals in the outer core of the Earth is known to influence the magnetic field, but this movement is chaotic and turbulent. Scientists do not fully understand how or why the movement happens.
- The study of the phenomena happening inside the Earth can only be done indirectly or through computer modelling, because of the extremely hot temperatures prevailing there. Scientists hope that this acceleration in the shifting of magnetic North pole would throw some new insights into the phenomena happening deep inside the Earth's surface.

What is the World Magnetic Model?

- ***James Clark Ross first sited magnetic North pole in 1831 in the scattered islands of Canada's Nunavut territory.*** Since then, the pole has largely marched North, passed through hundreds of miles over the last several decades.
- To keep up with all these changes, the US National Oceanic and Atmospheric Administration and the British Geological Survey developed a World Magnetic Model.
- The model is being updated every five years, with the last update in 2015. Between each update, scientists check the model's accuracy against data from ground magnetic observatories and the European Space Agency's Swarm mission – a trio of magnetic-field mapping satellites that zip around Earth 15 to 16 times each day.

What is Magnetic North Pole? How is it Different From Geographic North Pole?

The Earth has ***two north poles: geographic and magnetic***

- **Geographic North Pole:** It is the Northern axis around which the Earth rotates and is fixed. The North pole is located in the middle of the Arctic Ocean.

- **The Magnetic North Pole** (also known as the North Dip Pole) is a point on Ellesmere Island in Northern Canada where the Northern lines of attraction enter the Earth. A compass needle will point to the Magnetic North Pole – which is different from the **geographic North.**

Consequences

- The entire transportation sector, especially aviation and shipping, is dependent on knowing the position of magnetic North to chart out their navigation paths accurately. Similarly, it is vital for militaries, which need to know this for firing their missiles or for other purposes. ***Knowing the magnetic North is crucial for a number of civilian applications as well.***
- ***The compasses that are used in modern instrumentation are much more sophisticated, digital and more accurate.*** They need to be recalibrated to reflect the change in the magnetic North pole. The unscheduled release of the WMM has led to it.

EARTH'S MAGNETIC FIELD PROTECTS US FROM SPACE RADIATIONS

Dangerous particles, which are in the Earth's atmosphere, do not hit the Earth's surface because they are forced by the magnetic field around the Earth. Particles do enter at the funnels over the poles or they gain entry far downstream from the Earth. The particles that enter downstream or at the magnetotail (a narrow and elongated region of the magnetosphere of the Earth or of another planet that extends in the direction away from the Sun) cause the auroral lights.

The Aurora is an incredible light show caused by collisions between electrically charged particles released from the Sun that enter the Earth's atmosphere and collide with gases such as oxygen and nitrogen. The lights are seen around the magnetic poles of the Northern and Southern hemisphere. Auroras that occur in Northern hemisphere are called **Aurora Borealis** and those that occur towards the Southern hemisphere are called **Aurora Australis** or Southern lights.

Angle: The angle at which the magnetic field lines intersect the surface of the Earth ranges from 0 degrees at the equator to 90 degrees at the poles. ***Intensity:*** The magnetic field also varies in strength over the Earth's surface. It is strongest at the poles and weakest at the **equator.**

20.19 GAMMA-RAY BURSTS

Gamma-ray bursts (GRBs) are **extremely energetic explosions that have been observed in distant galaxies.** They are the brightest electromagnetic events known to occur in the universe. These bursts can last from ten milliseconds to several hours. These waves are generated by radioactive atoms in nuclear explosions. Gamma-rays can kill living cells; a fact which medicine uses to its advantage, using gamma-rays to kill cancerous cells. Gamma-ray bursts were discovered in the late 1960s by the US Vela nuclear test detection satellites. Gamma-rays come from solar flares (eruptions on the Sun's surface), pulsars (rotating objects which regularly emit radiation), nova and supernova explosions (explosions that cause stars to become extremely bright). They are strongly penetrating ionising radiations which means that they create charged radicals in any material they travel through. In the human body, they cause mutations in DNA and damage cellular mechanisms. In large doses, they are enough to kill cells and cause radiation poisoning.

21.1 PARTICLE PHYSICS

Particle physics is a branch of physics in the study of the elementary constituents of matter, radiation and the interactions between them. It is also popular with the name of 'high energy physics' because these elementary particles do not occur under normal circumstances in nature. It can be created and detected during energetic collisions of other particles due to particle accelerators.

Modern particle physics research is focussed on the basis of subatomic particles such as electrons, protons and neutrons (protons and neutrons are actually composite particles, made up of quarks), particles formed by the process of radiation and scattering, such as photons, neutrinos and muons, and a large number of exotic particles. The dynamics of particle physics are governed by quantum mechanics.

Various theories and models are given for the understanding of universe like **Event Horizon, Singularity, Standard Model, String Theory, etc.** Among these, standard model gained a lot of popularity.

21.2 STANDARD MODEL OF PHYSICS

All particles and their interactions are observed and described by a quantum field theory (under Standard Model).

The Standard Model classifies elementary particles into Quarks, Leptons, Bosons, etc., those that can combine and be found as various composite particles. The physics standard model concerns with the various particles' interactions, properties and characteristics at the subatomic level.

Scientists have been wondering from a long time regarding the evolution of the universe. To solve these mysteries, theoretical models are prepared to observe these realities. The standard model of physics explains the evolution of our universe, as it is observed today.

There are four fundamental forces exerted in nature: electromagnetic, strong (which binds atomic nuclei), weak (which governs radioactive decay and some fusion reactions) and gravitational forces. 'Theory of everything' unifies these four forces in one equation. Standard model unified the description of first three forces but not the existence of gravitational waves.

Often, the standard model is in news through recent advancements and latest discoveries. In this context, the basic knowledge is the key for understanding the recent discoveries such as gravitational waves or the neutrino particle and its masses.

The standard model of physics has been accepted globally, since the discovery of the Higgs boson.

After the latest discovery of gravitational waves and successful simulations of Big Bang at CERN, in all the analyses, the particle research has played the most important role. India has also gained an associate membership of CERN.

21.3 FUNDAMENTAL PARTICLES

21.3.1 Fundamentals of Bosons

In 2018, the 125th birthday of famous physicist Satyendra Nath Bose was celebrated, after whom Higgs Boson was named by CERN. Satyendra Nath Bose worked with Albert Einstein to develop the Bose–Einstein statistics, according to which bosons can overlap and coexist with other bosons.

All fundamental particles in nature can be divided into two categories, fermions or bosons.

- Particles that make up matter are called Fermions. Examples: electrons, protons, leptons, quarks, neutrinos.
- Particles that carry force are called bosons. They obey Bose–Einstein statistics.
    - Bosons are sometimes called force particles because they control the interaction of physical forces.
      Examples: photons, helium atoms, gluons, W Boson, Z Boson.

21.3.2 Quarks

In standard model of physics, quarks are the proposed elementary particles having six major quarks and six anti-quarks, carrying the fractional charge. The atomic particles are formed by the combination of different quarks. As the combination of two or more quarks leads to the formation of an integer (–1, 0, 1...) valued particle, termed as Hadron and the Hadron consists of three quarks which are called Baryons. Its examples are protons and neutrons. The protons are made from a combination of two up-quarks and one down-quark and neutrons are made from the combination of one up-quark and two down-quarks, respectively.

TERMINOLOGY

Event Horizon: Under general relativity is the concept of an event horizon. It is a boundary in spacetime beyond which there is no possibility of any events, e.g., the points at which the gravitational pull becomes so great as to make escape impossible, even for light, i.e., Black hole.

Singularity: It is a location in space-time where the gravitational field of a celestial body becomes infinite. When a star collapses beyond a certain point it would form a black hole, inside which a singularity (covered by an event horizon) would be formed. According to modern general relatively, the initial state of the universe, at the beginning of the Big Bang, was a singularity.

Standard Model: Our current knowledge about the subatomic composition of the universe is summarised in what is known as the **Standard Model** of particle physics. It describes both the fundamental building blocks out of which the world is made, and the forces through which these blocks interact. There are twelve basic building blocks. Six of these are **quarks** – they go by the interesting names of **up, down, charm, strange, bottom and top**. (A proton, for instance, is made of two up quarks and one down quark.) The other **six are leptons** – these include the electron and its two heavier siblings, the **muon** and the tau, as well as **three neutrinos**. Similar to standard model, String theory also explains about the study of universe.

21.3.3 Leptons

Leptons are also made up of six different types as similar to quarks, but they do not carry any fractional charge. **They consist of electron, muon, tau and three neutrino types.**

21.3.4 Higgs Boson/God Particle

Bosons are the combination of the particles carrying forces. Firstly, an Indian scientist, Satyendra Nath Bose discovered this type of particle but he could not get the attention of the scientist community. Later on, Peter Higgs further analysed these type of particle and got attention of the scientific community across the world. Due to first observation of God particle, Satyendra Nath Bose is also called the Father of God Particle. God particle is also popular with the name of 'Higgs Boson particle'. Due to the presence of God particle, every particle has mass. Gravity as a natural force has still not been accepted by the standard model, owing to its failure in discovering its boson. The strongest existing force is the nuclear force, whereas the force of gravity is the weakest. Within all fundamental particles (like proton, neutron, etc.) and in universe there is an existence of Higgs boson particle/God particle, for the existence of mass.

Higgs boson particle is present everywhere, as in proton and neutron and in the surroundings of quarks. According to scientists, Higgs field is also present in each and every planet. This is analogous to electric and magnetic field. Without this field, atoms, molecules, planets, stars and living organisms would not exist. Higgs field completely fills the universe.

Higgs boson is one of the fundamental particles, which on interaction with Higgs field gives mass to all particles. It was experimentally proved in the Large Hadron Collider at CERN in 2013.

(Refer **Infographic – CERN Experiment**)

21.4 CERN (EUROPEAN COUNCIL FOR NUCLEAR RESEARCH)

In the year 1952, as an interim agency, the CERN was set up for establishing the world's biggest nuclear and particle physics laboratory, with the aim of creating a world-class fundamental physics research organisation, near Geneva, along the **Swiss-France border.**

At CERN, the fundamental particles are forced to collide collectively in the collider at light speed, thereby providing clues to the physicists regarding the interaction of particles at such high speed and further providing the view of the creation of the universe by recreating the Big Bang.

BOSE–EINSTEIN STATISTICS

- Particles that have integer spin such as photons, several atoms, such as Gluon, W and Z boson and Higgs boson, fall under those categories of particles that show quantum mechanical behaviour, but do not obey the Pauli's exclusion principle. Such particles have integer values of spin and there must also be no significant interaction between the particles. The statistical behaviours of these particles was described by Satyendra Nath Bose, and Albert Einstein, and goes by their names as Bose–Einstein statistics. Particles obeying these statistics are called Bosons. Bosons are particles with an intrinsic spin of 0, 1, 2 or another integer.
- There are various matter particles such as electron, proton, neutron and neutrino except the photon. The photon is a quantum or tiny bundle of the electromagnetic field.
- The relation between matter particles and field quanta is simple as matter particles interact with each other by exchanging the appropriate field quanta.
- One fundamental difference between matter particles and field quanta is that while many field quanta can be squeezed into a small volume, but the matter cannot be. For example while sitting close to another person, there is a limit to how close you can get. This is because the electrons, protons, etc., in our bodies resist being stacked on top of each other. The same is not the case with field quanta, which can be as closely packed as needed.
- Matter particles such as electrons, protons, etc., obey the Fermi-Dirac statistics and are known as 'Fermions'. The fermions, governed by Fermi-Dirac statistics, are all particles with odd-half-integer spins – Yi, 3A, 5A, etc., and include the electrons, neutrinos, muons and all the quarks, the fundamental particles that make up protons and neutrons.
- Bosons particles at low temperatures, cause such strange phenomena as superconductivity, superfluidity and Bose–Einstein condensation. They also allow photons of the same frequency to form coherent laser beams. Fermions, on the other hand, avoid one another. Electrons around a nucleus stack into shells instead of collapsing into a condensed cloud, giving rise to atoms with a great range of chemical properties.
- Field quanta obey what is called Bose–Einstein Statistics and are collectively called 'Bosons'. There is the Higgs Boson which gives mass to particles like protons and neutrons after they collide in Higgs field. There are the W and Z Bosons associated with the weak force and the neutrinos which cause the particle to change and decay. Gluon is responsible for strong force which holds nuclei together.
- The Bose–Einstein distribution predicts that at very low temperatures, very nearly absolute zero, all particles in the system will condense into a single state, called the Bose–Einstein condensate. This was a prediction made around the year 1924. At that time, the experimental facilities available were not capable of attaining the low temperatures required to test this prediction. It took almost 70 years from the time of the prediction, for experimental facilities to evolve to the stage where it was possible to demonstrate the formation of this condensate. In 1995, Eric Cornell and Carl Weiman demonstrated the formation of the condensate using a small collection of Rb atoms, which they cooled to a few hundred nano Kelvin. For demonstrating the formation of the Bose–Einstein condensate, they were awarded the Nobel Prize in Physics for the year 2001 along with Wolfgang Ketterle.
- Bose had figured out (in the specific case of photons) how a group of identical photons would behave.
- The foundation of quantum statistics was laid by Bose when he was doing calculation on employing a technique utilising Planck's law of radiation using only quantum mechanical ideas. He then sent his paper to Albert Einstein who acknowledged the value of his calculation and had the paper translated into German and published in the journal Zeitschrift fur Physik. This paper turned out to be a seminal one and the technique used by Bose goes under the name of Bose–Einstein Statistics and the particles such as photons that obey these statistics are called Bosons.
- While Bose himself did not realise the enormous breakthrough he had made, Einstein did, and he took Bose's work much further. Physicist Paul Dirac was the first to use the term 'Boson' to describe the particles that obeyed Bose–Einstein statistics, in order to celebrate Bose's contribution to developing this theory.
- It revolutionised the field of Physics in three ways:
  - Improved the benchmark in terms of Particle Physics model.
  - Laid the foundation of 'God Particle' and helped Peter Higgs in winning a Nobel Prize.
  - Enhanced the benchmark of Standard Model of Particle Physics.
- Bose–Einstein statistics predicted that at very low temperature near absolute zero, all particles will condense into a single state, called Boson. This was a prediction made in 1920s. At that time, the experimental facilities were not capable of attaining the low temperatures to test such prediction.
- Over the years, experiments related to Bose–Einstein Statistics were carried out. Resultantly, all the fundamental particles were classified into two categories, the first one is 'Fermions' after Italian scientist Enrico Fermi, and the second one is 'Bosons' after Indian scientist Prof. Bose.

- Thus, 'Bose–Einstein Statistics' helped in improving the benchmark in terms of Standard Model of Particle Physics.

Discovery of God Particle

- Peter Higgs carried out further research in the year 1960 using Bose-Einstein Statistics and wrote a paper about a very unstable particle that survives for a fraction of a second after its birth, and then it breaks apart producing other fundamental particles. He termed this particle 'Higgs Boson Particle' or 'God Particle'. If scientists could produce such 'God Particle' in laboratory, it could further improve the Standard Model and our understanding of the universe.
- In early 2000s, world's largest particle accelerator called 'Large Hadron Collider (LHC)' was set up at CERN's laboratory in Europe. They carried out experiments and successfully discovered the God particle and confirmed the theory of Peter Higgs.
- Subsequently, Peter Higgs was given a Nobel Prize in Physics (2013).
- The Bose–Einstein Statistics helped CERN scientists discover God particle and thus improved the Standard Model of Particle Physics and our understanding of the Universe.

FUNDAMENTAL PARTICLES

Everything in the universe is made up of atoms. But what is an atom made of? Subatomic particles – Protons, Electrons and Neutrons, right? But there is a world beyond them. Experiments have confirmed that the subatomic particles are not indivisible but they can be further divided into 17 elementary or fundamental particles. These 17 elementary particles can be grouped into three major categories: quarks, leptons and bosons.

- Quarks and leptons constitute matter and so are called matter particles, whereas the bosons build up force and hence are termed force particles.
- Quarks are the fundamental constituents of matter. They are of six types: up quark, down quark, top quark, bottom quark, strange quark and charm quark. They combine to form composite particles called Hadrons. The hadrons are of two types: Baryons and Mesons. The baryons are made up of three quarks and the mesons are made up of one quark and one antiquark.
- The most common examples of baryons are protons and neutrons. The up quarks and down quarks build up the protons and neutrons. An Up Quark (UQ) carries a charge of +2/3 and a Down Quark (DQ) carries a charge of -1/3. So, we can see, even protons and neutrons could be broken down into smaller units.
- A proton is made up of two up quarks and one down quark. Hence, its resulting charge is +1(+2/3+2/3-1/3).

Elementary particles

Matter Particles			Force Particles	
Quarks	Leptons		Bosons	
Unitary	Charged	Neutral	Vector bosons	Scalar bosons
1. Up	7. Electron	10. Electro Neutrino	13. Photon	17. Higgs Boson
2. Down	8. Muon	11. Muon Neutrino	14. W boson	
3. Top	9. Tau	12. Tau Neutrino	15. Z boson	
4. Bottom			16. Gluon	
5. Strange				
6. Charm				

(Charge of 1UQ = +2/3; Charge of 1DQ = -1/3; 1 Proton = 2UQ + 1DQ = +2/3+2/3-1/3=+1)

A neutron is made up of one up quark and two down quarks. Hence, its resulting charge is 0 (+2/3-1/3-1/3).

(Charge of 1 UQ = +2/3; Charge of 1DQ = -1/3; 1 Neutron = 1UQ + 2 DQ = +2/3-1/3-1/3=0)

- Leptons are of six types and are grouped in two categories: charged leptons (electrons, muons and taus) and neutral leptons or anti-leptons (electron neutrinos, muon neutrinos and taus neutrinos). Electrons are the most stable type of leptons. The other types of leptons – muons and taus – also exist but they are very high energy particles and are not stable. Hence, they transform to their lower energy states, the electrons.

- Neutral particles called neutrinos also exist.
- Some people also theorise the existence of anti-neutrinos but nothing has been confirmed yet.
- Quarks and leptons both complete the picture of the atom.
- Bosons are also called force particles as there is a Boson 'causing' every fundamental force. Bosons are of two types: vector boson and scalar boson. There are four vector bosons: photons, W boson, Z boson and gluon. Photon (not proton) is the boson responsible for electromagnetic interaction. We commonly know it as the 'particle of light' which is nothing but an electromagnetic wave.
- W and Z bosons are responsible for the weak nuclear interaction or the force which binds the nucleus and the electrons.
- Gluons (derived from the word 'glue') are responsible for the strong nuclear interaction or the force that binds the protons and neutrons.
- A scalar boson called the Higgs Boson was discovered. ATLAS was involved in this jigsaw puzzle without which the world of elementary particles would be incomplete. The behaviour of Higgs Boson with other particles is still a mystery to be solved.
- These particles are responsible for imparting mass to other particles and what about the most fundamental force, gravity! Scientists are still not quite clear how to accommodate this force in the standard model. They have conceptualised a particle called 'gravitation' which they say is responsible for gravity but they are not quite sure.
- These 17 elementary particles and gravitation together complete the picture of the atom and its interactions as per the standard model of particle physics.

Since early 1960s, Indian scientists were involved in the research through the assistance of Department of Atomic Energy and Department of Science and Technology. The country was given the status of Observer at CERN in 2003 but India fully joined it as an Associate Member in 2016. Being the member of CERN, it will assist in increasing young scientists and engineers' participation in different projects and further help in bringing back the knowledge for its usage in the country's local programmes. This will give further opportunities to Indian companies for getting involved directly in CERN projects.

(Refer **Infographic – CERN Experiment**)

21.4.1 Large Hadron Collider (LHC)

The world's largest and highest-energy particle accelerator is the Large Hadron Collider (LHC). It is likely to solve the most basic question of physics, further facilitating the understanding of nature's laws through recreating the conditions of the 'Big Bang'.

The LHC is positioned in a tunnel with a circumference of 27 kilometres, and depth of 175 metres, under the border of France and Switzerland, near Geneva in Switzerland. This accelerator is designed for colliding the opposite particle beams of either protons or lead nuclei at very high energy. The hadrons are the particles consisting of quarks.

The LHC was created by CERN for testing different high-energy physics assumptions, consisting of the hypothesis of Higgs boson testing and other large new particles as predicted by different theories. It was formed in association with over 10,000 scientists and engineers from 100 countries, as well as hundreds of universities and laboratories.

21.4.2 Purpose of LHC

The formation of the LHC has given a hope to physicists for answering the basic questions relating to the fundamental laws, which govern the elementary particles' interactions and forces, the profound space and time structure and specifically, the quantum mechanics and general relativity intersection, where the present knowledge and theories are ambiguous. Moreover, there is a requirement of data from the high-energy particle testing for ascertaining the correctness of different scientific models' versions, such as those among the Standard Model of Physics and Higgsless model and validating their assumptions for further theoretical development. As per the expectation of many theorists, there will be emergence of new physics at the TeV-scale beyond that of the Standard Model on the basis of its unsatisfactory properties.

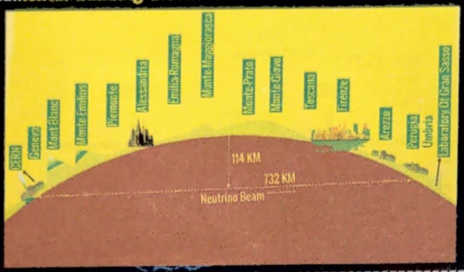
21.4.3 CERN Experiment

CERN performs experiments through various colliders (Cyclotron, Synchrotron and Large Hadron Collider), where we increase the speed of fundamental particles up

CERN EXPERIMENT

WHAT IS CERN EXPERIMENT?

- The CERN experiment and the discovery of the Higgs boson, often referred to as the "God particle," have revolutionized our understanding of particle physics. CERN, the European Organization for Nuclear Research, located in Switzerland, is home to the world's largest particle accelerator, the Large Hadron Collider (LHC).
- This ambitious project aims to probe the fundamental building blocks of the universe and unravel the mysteries of its origins.



- By colliding particles at incredibly high energies, the LHC allows scientists to recreate the conditions that existed just moments after the Big Bang.
- One of the most significant achievements at CERN was the discovery of the Higgs boson in 2012, a particle theorized to give mass to other particles through interactions with the Higgs field.

WHAT IS THE HIGGS BOSON OR GOD PARTICLE?

- The Higgs boson is the quantum particle associated with the Higgs field. Since the field cannot be observed directly, experiments have searched for the particle, whose discovery would prove the existence of the field and confirm the theory.
- On 4 July 2012, the ATLAS and CMS collaborations announced the observation of a particle consistent with the long-sought Higgs boson. The analyses performed since then by the two collaborations have confirmed that the particle discovered has the characteristics of the boson described by the theory.
- The search for the Higgs boson began in the late 1980s at CERN with the Large Electron-Positron (LEP) collider and continued with experiments at the Tevatron collider at Fermilab in the 1990s. The LHC, which replaced LEP, played a crucial role in the discovery of the Higgs boson in 2012.

MEMBER STATES OF CERN

MEMBER STATES (TOTAL-23)

Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovak Republic, Spain, Sweden, Switzerland and United Kingdom.

ASSOCIATE MEMBER STATES

- Cyprus, Estonia, and Slovenia are Associate Member States in the pre-membership stage at CERN.
- Croatia, India, Latvia, Lithuania, Pakistan, Türkiye, and Ukraine are also Associate Member States.

OBSERVER STATUS

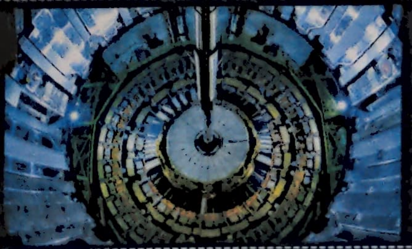
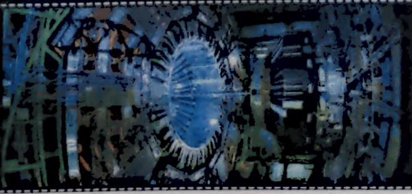
- Japan and the United States of America have Observer status for the LHC, and the United States also has Observer status for the HL-LHC.
- The European Union and UNESCO are international organizations with Observer status at CERN.
- The Observer status of the Russian Federation is currently suspended as per the CERN Council Resolution of 8 March 2022.

WHAT IS THE BROUT-ENGLERT-HIGGS MECHANISM?

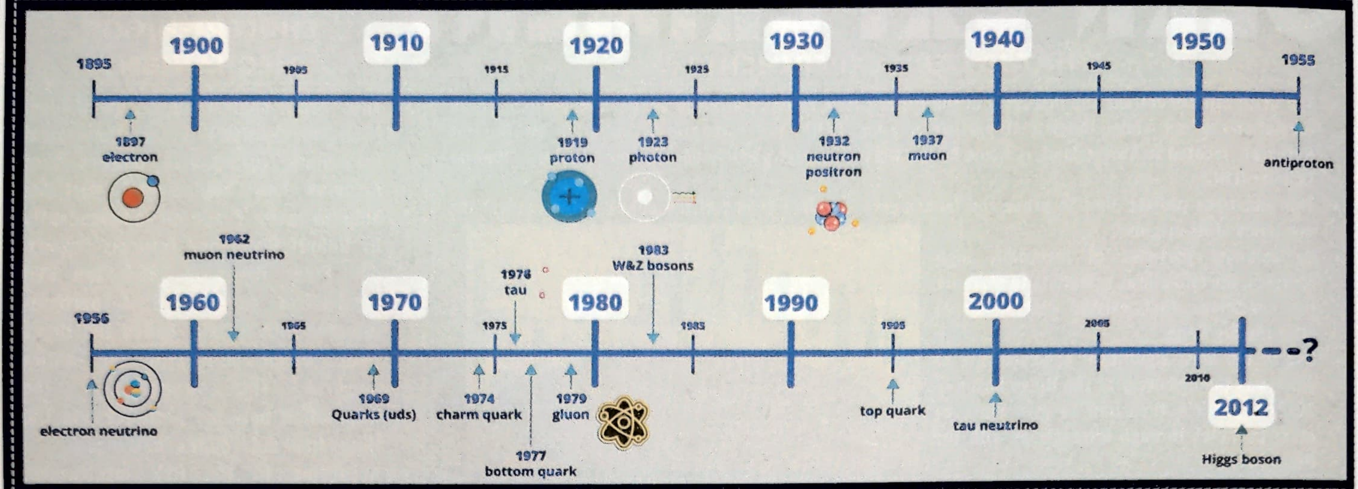
- The Brout-Englert-Higgs mechanism (BEH mechanism) is a theoretical framework in particle physics that explains how fundamental particles acquire mass. Proposed independently by Robert Brout and François Englert, and Peter Higgs in 1964, the BEH mechanism suggests that particles interact with a field, called the Higgs field, which permeates the entire universe. The strength of the interaction between particles and the Higgs field determines their mass.
- According to the BEH mechanism, particles that interact more strongly with the Higgs field acquire greater mass, while particles that do not interact with the field remain massless, like the photon. The existence of the Higgs field and its associated particle, the Higgs boson, was confirmed by experiments at the Large Hadron Collider (LHC) at CERN in 2012.
- The importance of the BEH mechanism and the discovery of the Higgs boson lies in its role in explaining the origin of mass in the universe. Prior to the development of this theory, the equations describing the electroweak force (the unified theory of the weak and electromagnetic forces) did not account for the masses of certain particles, such as the W and Z bosons. The BEH mechanism resolves this issue by providing a mechanism through which particles acquire mass, filling a crucial gap in our understanding of fundamental particles and their interactions.

LARGE HADRON COLLIDER (LHC)

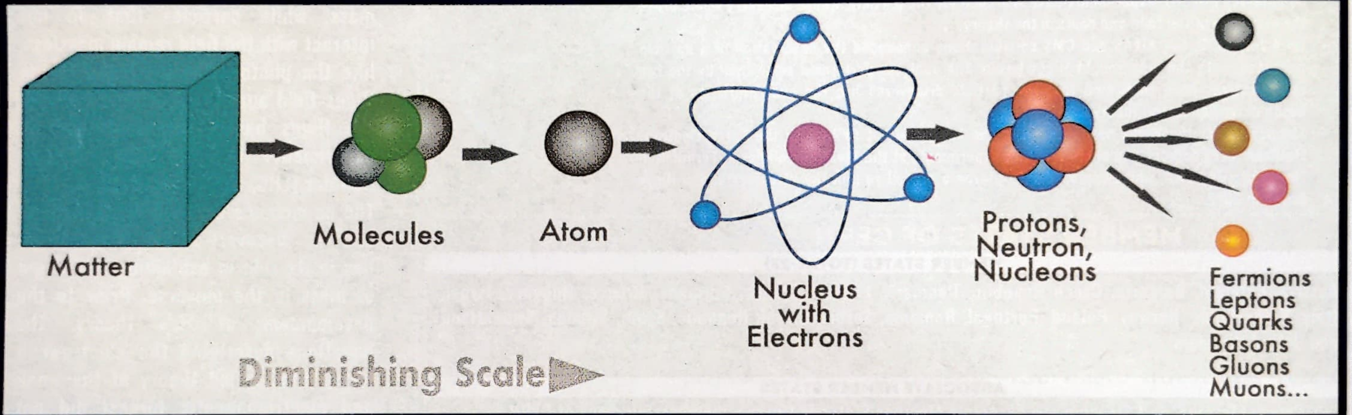
- The Large Hadron Collider (LHC) is the world's largest and most powerful particle accelerator.
- It first started up on 10 September 2008, and remains the latest addition to CERN's accelerator complex.
- The LHC is a 27-kilometre ring with superconducting magnets and accelerating structures. Two high-energy particle beams travel close to the speed of light, colliding in separate beam pipes at ultrahigh vacuum. Superconducting electromagnets guide the beams using special electric cable operating without resistance. The magnets are chilled to - 271.3°C using liquid helium for efficient operation.
- The LHC utilizes thousands of magnets, including 1232 dipole magnets (15 meters long) to bend the beams, and 392 quadrupole magnets (5-7 meters long) to focus the beams. Prior to collision, additional magnets "squeeze" the particles to increase collision chances. Colliding such tiny particles is like precisely firing two needles 10 kilometers apart to meet halfway.
- The CERN Control Centre centrally manages all controls for the LHC, its services, and technical infrastructure. The LHC beams collide at four locations around the accelerator ring, aligned with four particle detectors: ATLAS, CMS, ALICE, and LHCb.

KEY PARTICLE DISCOVERIES TIMELINE



HIERARCHY OF FUNDAMENTAL PARTICLES



BROOKHAVEN NATIONAL LABORATORY (BNL)

- Brookhaven National Laboratory (BNL) is a multi-disciplinary research facility located in Upton, New York, United States.
- It is operated by the U.S. Department of Energy (DOE) and is known for its contributions to various scientific fields, including nuclear and particle physics, materials science, and biology.
- BNL is home to several major research facilities, such as the Relativistic Heavy Ion Collider (RHIC) and the National Synchrotron Light Source II (NSLS-II).
- It collaborates with scientists from around the world and conducts cutting-edge research in fundamental and applied sciences.
- Atoms of antimatter have been trapped and stored for the first time by the ALPHA collaboration, an international team of scientists working at CERN, the European Organization for Nuclear Research near Geneva, Switzerland. Scientists from the U.S. Department of Energy's Lawrence Berkeley National Laboratory and the University of California at Berkeley have made key contributions to the ongoing international effort.

to the speed of light and fuse them in opposite direction at last within LHC. Within a second, millions billions times have fusion of these hadron particles become possible and we observed the presence of fundamental particles through various detectors. Seven types of detectors are used inside Large Hadron Collider: ALICE, ATLAS, CMS, LHCb. In this experiment, the presence of God particle/Higgs boson particle was proved. In this CERN experiment, the presence of antimatter was also proved during this collision. But, development of this antimatter through artificial means is very costly. In the study of LHCb detector, it proved that standard model is not accurately correct in many aspects like dark matter, etc.

A particle accelerator is a device that uses electromagnetic fields to propel charged particles to high speeds and to contain them in well-defined beams. An ordinary CRT television set is a simple form of accelerator. Particle accelerators come in two basic types: Linear – Particles travel down a long, straight track and collide with the target; e.g: Linac; and Circular – Particles travel around in a circular orbit until they collide with the target; e.g: Cyclotron, Synchrotron and Large Hadron Collider (LHC). **Superconducting magnet** is used in all accelerators to increase the speed of proton (hadron) so collision will proceed with very high potential to give a better result inside the detector.

21.4.4 India's Contribution at CERN

Indian scientists have been collaborating with CERN for the LHC experiment since 1991. India contributes about 100 scientists to the LHC. Indian scientists have put together crucial components to activate the LHC much below the sanctioned costs. All precision-made jacks on which the entire machine rests were made in India. Nearly 2,000 corrector magnets and circuit breakers were also made in India. The development of the machines gave the Indian scientists an opportunity to work on technologies of the highest level, validating the country's capabilities. India's involvement in the project has put the country in the big league. CERN granted India 'observer' status. Work on LHC's sequel, the 33-kilometre-long International Linear Collider, amply indicates the high value that Indian scientists now command.

4.5 Brookhaven and the Belle-II Experiment

Japan's made Super KEKB particle accelerator was used for Belle II experiment, that started in March 2019. The purpose of the upgraded Belle II experiment is to search for new physics phenomena that cannot be explained by the particles and forces already included in the Standard Model. A key part of this experiment is performed by using computing resources and expertise at the US Department of Energy's Brookhaven National Laboratory, the lead laboratory for US collaborators on Belle II Experiment.

This experiment observed the decay products streaming from collisions of electrons and positrons to seek answers about the understanding of Universe. The observed differences are, however, not sufficiently large to explain why today's universe is made of matter rather than a mix of matter and antimatter. Additional sources of matter–antimatter asymmetry must exist and, if observed, could indicate that some new, previously undiscovered particles might be taking part in the action. To identify such unobserved phenomena, scientists must analyse many times more heavy flavour meson decays than have ever been produced at past electron–positron facilities. Belle II will accumulate more than 50 times the data sample of the original Belle experiment at KEK, which itself produced 760 million such events.

Physicists at Brookhaven Lab play a leading role in searches for new sources of matter–antimatter asymmetry by studying decays of charm mesons. While the existence of matter–antimatter differences in beauty mesons have been known since decades, they have been observed only recently in charm decays by the LHCb experiment at CERN, the European laboratory for particle physics research. Studies at Belle II will complement those ongoing at LHCb and will allow to understand whether the observed matter–antimatter asymmetry can be explained by the Standard Model or it is caused by new phenomena.

Computing

The Belle II experiment produces multiple petabytes of data each year. Brookhaven Lab's Scientific Data and Computing Centre (SDCC) hosts an entire copy of the raw data and a huge fraction of the simulation and selection data, together with an archive of the detector's conditions at the time of each recorded collision. The SDCC also provides the computing resources necessary to reconstruct and analyse the data. The team at Brookhaven is also developing the data-distribution software for sharing Belle II data with collaborators around the world, working with Belle II colleagues and colleagues at CERN, learning from their experience managing datasets from the Large Hadron Collider as well as Brookhaven's own experience at the RHIC & ATLAS Computing Centre.

SuperKEKB Accelerator

To keep collision rates high, the electron and positron beams that circulate inside SuperKEKB must be tightly focussed. But the magnetic fields guiding the particles in one beam can have unwanted effects in the adjacent beam, causing the particles to spread. To fine-tune the fields of the accelerator magnets and counteract these adjacent-beam effects, Brookhaven's magnet division constructed 43 custom-designed corrector magnets. These corrector magnets are installed on each side of the Belle II detector, making adjustments to both the incoming and outgoing beams to maintain high beam intensity, or 'luminosity'. High luminosity results in higher collision rates, so physicists at Brookhaven and around the world will have more data to analyse.

21.5 NEUTRINO

21.5.1 Concept of Neutrinos and Its Importance

Neutrinos are the fundamental particles that were first formed at the beginning of the early universe, even before atoms could form. They are also continually being produced in the nuclear reactions of stars, like our Sun, and nuclear reactions here on Earth.

They are formed from the radioactive elements' decay and are the most abundant particles in the cosmos after the photons. They proliferated into solid matter over large distances and are very small in size equivalent to the tiny mass fraction of the proton having mass. Neutrinos are of three types, termed as flavours consisting of electrons, muons and tau particles. The major difference between them is that neutrinos are electrically neutral, whereas the electron, muon and tau are electrically charged.

It is very hard to detect the neutrinos, as they do not interact with other matter. But with the usage of special equipment situated in profound underground laboratories, it has become easier for scientists in the detection and discovery of neutrino and its various other properties, where it is not impossible for the penetration of other cosmic particles. The neutrino was postulated first by **'Wolfgang Pauli'** in 1930 to explain how beta decay could conserve energy, momentum and angular momentum (spin).

Neutrinos are so abundantly available around us that each second, nearly greater than 100 trillion of them passing right through us without our observation. Due to this very reason, INO is required to be constructed deep into the Earth, nearly 1,300 metres in depth. The existence of neutrino in the universe is from almost 13.6 billion years ago, same as the age of universe.

There is occurrence of three different types of neutrinos, such as $\nu\varepsilon$, $\nu\mu$ and $\nu\tau$ and are also divided in terms of different masses. From the recent experiments, neutrinos are known to have a tiny mass, but the order of their mass states is unknown and is one of the major unanswered questions nowadays. This big challenge may be solved by the INO, thereby concluding our neutrino image.

There are three different reasons through which the neutrinos are very much vital for our scientific growth and technological advancement. Firstly, they are abundantly available. Secondly, they have very tiny mass and no charge and hence can easily move irrespective of any interaction through planets, stars, rocks and human bodies. In reality, a trillion neutrinos can move thousands of kilometres throughout a rock before the occurrence of any interaction between the neutrino and a single rock atom. Thirdly, there is a huge information pool hidden under them, which would create a new panorama in astronomy and astrophysics, communication and in medical imaging fields.

Moreover, the neutrinos have the following additional significance.

- **Firstly,** in the field of nuclear non-proliferation, neutrinos play a key role through the monitoring of nuclear reactors.
- **Secondly,** the usage of neutrinos assists in the detection of mineral and oil deposits deep inside the Earth. The Neutrinos have the property of altering their 'flavour', depending on their length of movement and the quantity of matter in the way they have passed through, which can help us in identifying the untimely geological defects deep inside the Earth, thereby answering our question of an early warning system against earthquakes. In this field only, the Geo-neutrinos are applicable. Their swift analysis through neutrino monitoring stations, which is termed as a process called Neutrino Tomography, can give us significant seismological data, thereby detecting early turbulence and vibrations created by earthquakes.
- **Thirdly,** as the neutrinos can travel through the earth, which can unlock the faster way of sending data than the current 'around the Earth' model, with the usage of towers, cables or satellites. This system of communication may be transmission losses free as the usage of neutrinos hardly react with any atoms on their way, thus establishing a new panorama for telecom and Internet services. As per few scientists, if there is any sign of any extraterrestrial life form, then the quickest way for making communication with them is neutrinos.
- **Fourthly,** the neutrinos are the carriers of information regarding the universe and India's effort at INO in examining the neutrinos can facilitate in opening the universe's deepest mystery.

As 95 per cent of universe is made up of dark matter and dark energy, and as per the belief of few scientists, the neutrino research will assist in understanding the dark matter.

The only way to solve the biggest mystery of dark matter is neutrinos, which can further alter our concepts in the understanding of the universe and physics. The probing of this dark matter can only be undertaken in INO. Due to this, the scientists consider neutrino is the only mode in accessing some of the most incredible technologies, and consequently, with INO, India is confident of undertaking its correct place at the helm of neutrino research.

SOURCES OF NEUTRINO

1. **Artificial:** The major source of human-generated neutrinos is the nuclear reactors. Anti-neutrinos are formed during the fission process in the beta-decay of neutron-rich daughter fragments.
2. **Geological:** Neutrinos are part of the natural background radiation.
3. **Atmospheric:** Atmospheric neutrinos result from the interaction of cosmic rays with atomic nuclei in the Earth's atmosphere, creating showers of particles, many of which are unstable and produce neutrinos when they decay.
4. **Solar:** Solar neutrinos originate from the nuclear fusion powering the Sun and other stars. When four protons fuse to become one helium nucleus, two of them have to convert into neutrons, and each such conversion releases one electron neutrino.
5. **Supernovae:** Neutrinos are an important product of Types Ib, Ic and II (core-collapse) supernovae. In such events, the density at the core becomes so high that the degeneracy of electrons is not enough to prevent protons and electrons from combining to form a neutron and an electron neutrino.

21.5.2 Neutrinos Oscillation

The bulk neutrinos are received by the Earth from the sun itself. Over the years, scientists have been finding out an anomaly between the observed and the theoretical data of the neutrinos. As per the studies undertaken by Japan's **Super-Kamiokande detector**, up to two-third of the neutrinos were lost in measurements performed on Earth. This phenomenon is explained by the process termed as neutrino oscillation in which three neutrinos 'metamorphosise' into one another, implying that neutrinos have mass, though, very little.

21.5.3 IceCube

It is a particle detector positioned at the South Pole, which records the interactions of subatomic particles having no mass, termed as the neutrinos.

(Refer **Infographic – Neutrino & Antineutrino**)

21.5.4 Baikal-GVD (Gigaton Volume Detector)

The world's biggest underwater neutrino telescopes named as Baikal-GVD (Gigaton Volume Detector) is currently being launched by the Russian Scientists in Serbia's **Lake Baikail, the world's deepest lake.**

- It is **among the world's three largest neutrino detectors together with the IceCube at the South Pole and ANTARES** in the Mediterranean Sea.
- It aims **to study the mysterious fundamental particles termed as neutrinos in detail** and to probably find out their sources.

REASON BEHIND OPPOSITION

Tamil Nadu has made clear to the Supreme Court that it does not want **the Indian Neutrino Observatory (INO)** to be set up in a sensitive ecological zone in the Western Ghats at great cost to wildlife, biodiversity, and by ignoring the local opposition and public agitations to the project.

Why is it being opposed?

- The project in question falls exactly on the hill slopes of the part of the Western Ghats, which aligns within it a significant tiger corridor, namely **the Mathikettan-Periyar Tiger corridor.**
- This corridor links the **Periyar Tiger Reserve** along the Kerala and Tamil Nadu borders and **the Mathikettan Shola National Park.**
- The proposed project area also ecologically links to the eastern habitats, where **Srivilliputhur Meghamalai Tiger Reserve** is located. It hosts tigers from this region and helps in genetic dispersal.
- The area is a significant watershed and catchment zone for **the rivers Sambhal and Kottakudi.**

21.5.5 Indian Neutrino Observatory (INO)

The **India-based Neutrino Observatory** (INO) Project is **a multi-institutional effort** aimed at building a world class **underground laboratory** with a rock cover of approx.1200 m **for non-accelerator-based high energy and nuclear physics research in India.** The initial goal of INO is to **study neutrinos.**

(Refer **Infographic – Neutrino & Antineutrino**)

21.6 THEORY OF RELATIVITY

German scientist Albert Einstein proposed the 'Theory of Relativity' under two heads, i.e., Special Relativity (1905) and General Relativity (1915). A lot of assumptions underlying earlier physical theories were ousted by Einstein, enumerating the basic concepts of space, time, matter, energy and gravity. Specifically, relativity gives the fundamentals that are essential for the cosmic processes and understanding the universe's structure. The Nobel Prize in Physics 1921 was awarded to Albert Einstein 'For his services to Theoretical Physics and especially for his discovery of the law of the photoelectric effect'.

Observers who are experiencing constant velocity are accounted for by Special Relativity, whereas General Relativity covers those who are experiencing acceleration.

Special Theory of Relativity 'Special Relativity' is restricted to those objects, which move at constant speed in a straight line, termed as the inertial motion. A frame of reference, either at rest or moving with a uniform velocity, is known as the inertial frame. As per the theory of special relativity – the speed of light is a maximum limit, which can be approached but not by any material object – forms the basis of the most famous physics equation that is $E = mc^2$.

General Theory of Relativity 'General relativity' is linked with gravity being the universe's most fundamental force. Gravity describes the macroscopic behaviour, and consequently general relativity explains the physical phenomena such as planetary dynamics on larger scale. The applications of relativistic effects are there in basic science related to civilian and military technology. The theory $E = mc^2$ is vital in the study of subatomic particles, thereby determining the energy needed to form particles or for converting them from one type to another and the releasing of energy when the particles get destroyed. A 2016 research confirms Einstein's theory of relativity. Einstein compared the universe's shape to a single fabric. According to theory of relativity, the force of gravity is the result of curvature in this space-time. The theory of relativity describes that the laws of physics are similar everywhere. In short, it can predict everything from the existence of black holes, to light bending due to gravity, to the behaviour of Planet Mercury in its orbit.

EINSTEIN'S THEORY OF RELATIVITY

As per the Theory of General Relativity, **under the condition of no air resistance, all objects fall at the same rate in the same gravitational field.** For instance, if you drop a bowling ball (heavy item) and a tiny marble (lighter item), off a building, both will hit the ground at the exact same time. **The difference in mass and composition do not affect the timing of the fall at all.** The researchers found in a year long research that **no detectable difference indicating no alternative theories of gravity were in motion.** These results were consistent with Einstein's theory of relativity.

The theory of general relativity

- In 1915, Albert Einstein propounded his theory of general relativity, which proposed that gravity itself was the result of warping of space-time by massive objects like stars and planets.
- Einstein's theory of relativity indicates that all objects fall the same way regardless of mass or composition.

Things predicted by General relativity include

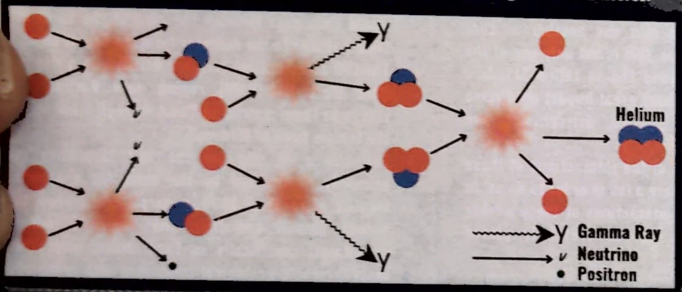
- ***Light bends towards the Sun when it gets closer to the Sun.***
- ***The perihelion of the planet Mercury rotates along its orbit more than is expected:*** General relativity accounts for the difference between what is seen and what is expected without it.
- ***Redshift from gravity:*** The light is stretched into longer wavelengths when lights move away from an object with gravity (moving away from the centre of the valley).
- ***The Shapiro delay:*** Light seems to slow down when it passes close to a massive object.
- ***Gravitational waves:*** They were first observed on 14th September 2015.

- A few years back, old televisions used to have cathode-ray tube screens. The working of cathode ray, which helps in the manufacturing of these televisions, works on the theory of relativity.
- We all are using electricity, and it has become an integral part of our lives. A generator, transformer, all the things which produce electricity are based on this theory. Magnetism is also influenced by this theory.

NEUTRINO & ANTI-NEUTRINO

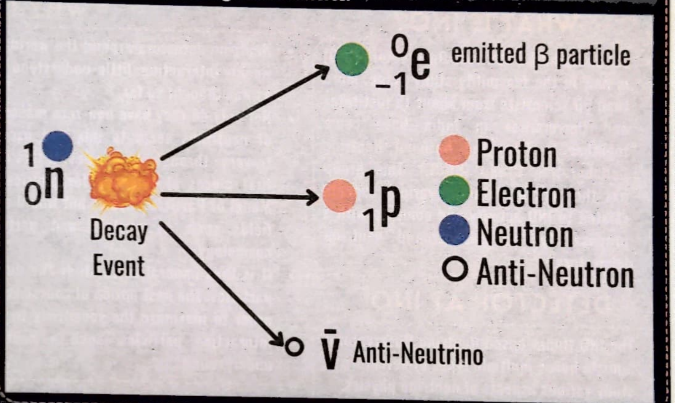
NEUTRINO

- Neutrinos are subatomic particles that belong to the family of leptons, which also includes electrons, muons, and tau particles.
- They are fundamental particles, meaning they are not composed of smaller particles.
- Neutrinos are electrically neutral, meaning they have no electric charge, and they interact very weakly with matter. They have an incredibly small mass, although it was long believed to be zero. However, recent experiments have confirmed that neutrinos do have a tiny but non-zero mass.
- Neutrinos are an essential component of the Standard Model of particle physics, which describes the fundamental particles and their interactions. According to the Standard Model, there are three types, or "flavors," of neutrinos: electron neutrinos, muon neutrinos, and tau neutrinos. Each type of neutrino is associated with a specific charged lepton: electron, muon, or tau.
- Neutrinos are produced in various natural processes, such as nuclear reactions in the Sun's core, radioactive decays, and high-energy cosmic events like supernovae. They are also created in particle accelerators and nuclear reactors.
- Due to their weak interactions, neutrinos can pass through matter almost unaffected, making them challenging to detect. However, specialized detectors, such as massive underground or underwater experiments, have been developed to observe neutrino interactions indirectly. These experiments have contributed to significant discoveries, such as confirming the phenomenon of neutrino oscillation, where neutrinos can change their flavor as they travel through space.
- The study of neutrinos is crucial in understanding the fundamental properties of matter, the origins of the universe, and the behavior of particles in extreme environments. Neutrino research has profound implications for astrophysics, cosmology, and our understanding of the fundamental laws that govern the universe.



ANTI-NEUTRINO

- Anti-neutrinos are the antiparticles of neutrinos. Like neutrinos, they are electrically neutral and have very low mass. However, anti-neutrinos have opposite lepton flavors compared to their corresponding neutrinos.
- Just as particles have antiparticles with opposite electric charges, anti-neutrinos are associated with the antimatter counterparts of the charged leptons. The three flavors of anti-neutrinos are electron anti-neutrinos, muon anti-neutrinos, and tau anti-neutrinos, corresponding to the antiparticles of the electron, muon, and tau particles, respectively.
- Anti-neutrinos are produced in various processes similar to those that generate neutrinos. For example, they are emitted in nuclear reactions, such as beta decay, where a neutron is transformed into a proton, emitting an anti-neutrino and a beta particle (electron or positron).
- Similar to neutrinos, anti-neutrinos interact very weakly with matter. They can pass through large amounts of material without being significantly absorbed or scattered. However, like neutrinos, they can still interact via the weak nuclear force, allowing them to be detected using specialized experiments and detectors.
- The study of anti-neutrinos provides insights into the nature of antimatter and the symmetries between matter and antimatter. The detection and analysis of anti-neutrinos are essential in fields such as particle physics, astrophysics, and nuclear physics, contributing to our understanding of fundamental particles, the behavior of neutrinos, and the workings of the universe.



WHAT IS ICECUBE NEUTRINO OBSERVATORY?

- The IceCube Neutrino Observatory is the first detector of its kind, designed to observe the cosmos from deep within the South Pole ice. An international group of scientists responsible for the scientific research makes up the IceCube Collaboration.
- Encompassing a cubic kilometer of ice, IceCube searches for nearly massless subatomic particles called neutrinos. These high-energy astronomical messengers provide information to probe the most violent astrophysical sources: events like exploding stars, gamma-ray bursts, and cataclysmic phenomena involving black holes and neutron stars.
- The Antarctic neutrino observatory, which also includes the surface array IceTop and the dense infill array DeepCore, was designed as a multipurpose experiment. IceCube collaborators address several big questions in physics, like the nature of dark matter and the properties of the neutrino itself. IceCube also observes cosmic rays that interact with the Earth's atmosphere, which have revealed fascinating structures that are not presently understood.
- Approximately 300 physicists from 58 institutions in 14 countries make up the IceCube Collaboration. The international team is responsible for the scientific program, and many of the collaborators contributed to the design and construction of the detector. Exciting new research conducted by the collaboration is opening a new window for exploring our universe.
- The National Science Foundation (NSF) provided the primary funding for the IceCube Neutrino Observatory, with assistance from partner funding agencies around the world. The University of Wisconsin–Madison is the lead institution, responsible for the maintenance and operations of the detector. Funding Agencies in each collaborating country support their scientific research efforts.

WHAT IS ICECUBE NEUTRINO OBSERVATORY TRYING TO FIND?

- IceCube detects light emitted by charged particles that are produced when a single neutrino crashes into a proton or neutron inside an atom. The resulting nuclear reaction produces secondary particles traveling at high speeds (faster than light in the ice!) that give off a blue light called Cherenkov radiation. The neutrinos we detect are like fingerprints that help us understand the objects and phenomena where the neutrinos are produced.

WHY IS ICECUBE IMPORTANT?

- IceCube, a fundamental research endeavor, has the potential to lead to astounding discoveries while offering new insights into the mysteries of our universe. By exploring the invisible realms of dark matter and dark energy, IceCube's study of neutrinos may uncover unexpected phenomena and deepen our understanding of the composition of the universe.

HOW BIG IS ICECUBE?

- IceCube covers one cubic kilometer. It has an area of approximately 1 square kilometer and is 1,000 meters deep, with the top of the detector array buried in the ice at a depth of about 1,500 meters (4,920 feet).

WHY BUILD ICECUBE AT THE SOUTH POLE?

- In order to detect the light given off by the secondary particles produced by neutrino interactions, we needed a large volume of transparent material. That basically meant water or ice. Because these interactions are rare and produce light that can extend over a kilometer, IceCube requires a lot of ice atoms to capture one event. The South Pole is the one place on Earth that holds such large quantities of clear, pure, and stable ice and has the infrastructure to support scientific research.
- Most ice contains air bubbles that would distort IceCube's measurements, but the South Pole ice sheet is very thick and tightly compressed. As snow and ice piled up over time, the lower layers of ice were compressed. The immense pressure forced out air bubbles, making the deep ice ultra-transparent.
- IceCube not only needs clear, pure, and stable ice to make its discoveries; it also needs to be shielded from radiation at the Earth's surface. IceCube's individual sensors, called digital optical modules, or DOMs, are buried in the ice beginning at a depth of about 1,500 meters (4,920 feet, almost a mile) below the surface. The 1,500 meters of ice above the detector help to shield it from natural radiation at the Earth's surface.
- The South Pole station, constructed on three kilometers of clear ice, presented an opportunity to satisfy all the requirements needed to build the detector.

WHO IS IN CHARGE OF THE DETECTOR?

- The IceCube Collaboration runs the project and the University of Wisconsin–Madison (UW) is the lead institution. UW led construction of the IceCube proof-of-concept project called AMANDA, and in evaluating proposals from several institutions, the National Science Foundation determined that UW had the experience and success to oversee IceCube.

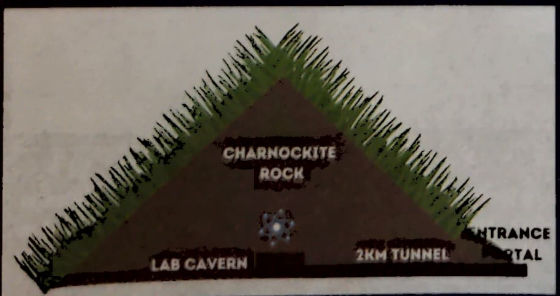
INDIA-BASED NEUTRINO OBSERVATORY (INO)

WHAT IS INO?

- The India-based Neutrino Observatory (INO) is now in the feasibility study stage. More than 50 scientists from about 15 Institutes and Universities in India have come together to form the **National Neutrino Collaboration Group (NNCG)**. This group has the task of detailing various aspects related to INO activity and come up with a proposal for an underground neutrino laboratory.

DETECTOR AT INO

- The INO (India-based Neutrino Observatory) aims to house multiple types of detectors to study various aspects of neutrino physics.
- In the first phase, the focus will be on studying atmospheric neutrinos generated by cosmic ray interactions in Earth's atmosphere.
- Neutrinos and antineutrinos of different flavors are produced in these interactions.
- To identify neutrino and antineutrino interactions separately, an iron calorimeter (ICAL) will be used. ICAL consists of horizontal layers with detector material triggering when a charged particle passes through it.
- By creating a uniform magnetic field inside the detector using solenoidal coils, the charged particles bend, allowing for charge identification, energy measurement, and momentum estimation.



WHY INO?

- Neutrino detectors around the world seem to see evidence that these weakly interacting, little-understood particles are not really massless, as was thought so far.
- Not only do they have non-zero masses, different species (or flavours) of neutrinos seem to mix and oscillate into one another as they traverse through the cosmos. If this is true, this is not only one of the first pieces of evidence for physics beyond the so-called Standard Model of Particle Physics but would also have great impact on diverse fields such as nuclear and particle physics, astrophysics and cosmology.
- It is thus imperative to study the details of the interactions of these particles. The best option of course is to have a lab in order to do so. In order to maximize the sensitivity to the interactions of these weakly interacting particles, such a neutrino lab is necessarily placed underground.

WHAT CAN ICAL AT INO TELL US ABOUT NEUTRINOS?

- The Super-Kamiokande and SNO experiments have provided evidence of neutrino oscillation, indicating that different neutrino flavors mix and oscillate into each other.
- However, these experiments have mainly observed a depletion in the expected neutrino spectrum. To further confirm oscillation, both depletion and enhancement need to be observed.
- ICAL, with its ability to study the spectra of muons from atmospheric neutrinos, aims to establish the "trough and peak" effect, providing a clear oscillation pattern and determining oscillation parameters accurately.
- Additionally, ICAL's capability to distinguish neutrino and antineutrino events allows for studying Earth-matter effects and exploring poorly-known oscillation parameters.

WHY DETECT NEUTRINOS?

- Neutrinos have non-zero masses, but their exact values for the three types are still uncertain due to detection challenges.
- Despite their small masses, neutrinos can significantly affect the evolution of the Universe through gravitational effects.
- Direct determinations of neutrino masses and properties are essential for understanding fundamental questions about the Universe's origin and stellar energy production. Neutrinos also offer the exclusive opportunity for neutrino tomography to study the Earth's structure, particularly its deep interiors.

LOCATION OF INO

- An underground neutrino facility in India offers the unique possibility of locating a neutrino detector near the Earths equator. This can have some very interesting consequences for solar neutrinos which would then pass through the core of the Earth in their passage to the detector from the Sun at night.
- The INO collaboration has now decided on a site in Bodi West Hills(BWH) region near Pottipuram village in Theni district of Tamil Nadu (110 km from the temple town of Madurai).
- The choice of site for the INO laboratory is primarily determined by the need for a cavern located more than 1000 meters underground to reduce cosmic radiation. The southern Indian mountains, specifically in Tamil Nadu, offer the most favorable geological conditions with compact, dense rock, predominantly gneiss. The region also provides access to water and power, along with easy site accessibility for efficient operations. These factors make the mountains of Tamil Nadu an attractive and safe location for the INO laboratory.

WHY UNDERGROUND LABORATORY?

- Neutrinos have weak interactions with matter, making them difficult to detect in a laboratory. The high background from cosmic rays and natural radioactivity hinders their detection on the Earth's surface. Therefore, most neutrino observatories are located deep underground.
- One of the earliest underground laboratories for neutrino detection was situated over 2000 m deep at the Kolar Gold Field (KGF) mines in India. However, it has been closed due to mine closure. Presently, many underground laboratories worldwide, situated at depths of a kilometer or more, are either located in mines or road tunnels. Major laboratories exist in Sudbury (Canada), Kamioka (Japan), Gran Sasso (Italy), and Soudan mines (USA). The INO project aims to recapture the pioneering neutrino studies conducted at KGF and is among the planned underground laboratories.
- These underground facilities offer reduced background noise from cosmic rays and enable more effective neutrino detection, allowing for advancements in neutrino research.

GRAVITATIONAL LENSING

- Gravitational lensing is an **effect of Einstein's theory of general relativity** – simply put, **mass bends light.**
- The gravitational field of a massive object will extend far into space, and cause light rays passing close to that object (and thus through its gravitational field) to be bent and refocused somewhere else.
- The more massive the object the stronger its gravitational field and hence the greater the bending of light rays – just like using denser materials to make optical lenses results in a greater amount of refraction.

Benefits

- Gravitational lensing is useful to cosmologists because it is directly sensitive to the amount and distribution of dark matter.
- Lensing can help astronomers work out exactly how much dark matter there is in the universe as a whole and also how it is distributed.

Lensing has also been used to help verify the existence of dark matter itself.

- Relativity is the reason behind the conversion of mass and energy, working of nuclear power plants, and why the Sun shines. Another important effect is in supernova explosions, which signals the death of massive stars. Another important aspect of this theory in present scenario is GPS, for proper functioning of GPS this theory has to be taken into account.

100 Years of Theory of Relativity

Theory of relativity completed its centennial anniversary in 2015. It was given by Albert Einstein in the year 1915 and is considered the most revolutionary theory to human kind.

21.7 GRAVITATIONAL WAVES

Refer **Infographic - Gravitational Waves - Ripples in Space Time.**

Gravitational wave observatories are installed in many places **(Figure 21.1)** and also work in future for better understanding of gravitational waves: **Hanford** in Washington (Operational), **Livingston** in Louisiana (Operational), GEO600 in Germany (Operational), **Virgo** in Italy (Operational), **KAGRA** in Japan (Operational), India (Planned).

21.7.1 LISA Pathfinder, LISA and eLISA

LISA mission detects the gravitational waves which **might also approach from other remote systems** such as Extreme Mass Ratio Inspirals (EMRIs) **which are smaller stellar mass black holes** orbiting supermassive black holes. Gravitational waves study provides **vast potential for the discovery of those universe parts** such as black holes, the Big Bang, unknown objects, etc., **which are invisible** by other means. **LISA will supplement our information about the universe's beginning, evolution and structure.**

LISA Pathfinder Mission

LISA Pathfinder, a LISA proof-of-concept mission was initiated on December 3, 2015 which tests within the spacecraft, the free-floating test masses that are small enough in comparison to an anticipated gravitational wave signal. After the completion of its **mission in 2017, LISA Pathfinder has demonstrated that the outstanding noise levels exceeds the original requirements by a factor of ~100.** The mission also surpassed the full LISA mission requirement, indicating that major technology is in progress for LISA.

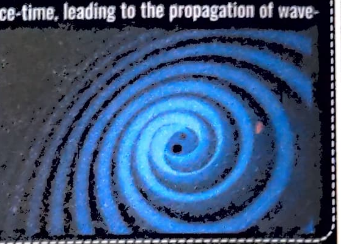
A Different Frequency Range from Different Objects

A wide frequencies range are being covered by the gravitational wave spectrum. In comparison to LIGO's frequency of 10 Hz to 1000 Hz, LISA functions in the frequency range between 0.1 mHz and 1 Hz which is very low. The differentiation pertains to the concept that the LISA is searching for waves having a much longer wavelength, consequent to objects which are much heavier and in wider orbits than those for which LIGO is seeking for, thereby opening up the detection sphere to a wider range of sources of gravitational wave.

LISA consists of three spacecrafts forming in space an equilateral triangle where the triangle sides are also termed as the LISA's 'arms', thereby extending nearly a million miles. Hence, in space, **LISA can shun the noise and access spectrum regions which are inaccessible from Earth owing to these particularly long arms.** LISA discovery of the gravitational wave sources consists of Galaxy's ultra-compact binaries, supermassive black hole mergers, and extreme mass ratio inspirals, between other unusual possibilities.

GRAVITATIONAL WAVES – RIPPLES IN SPACETIME

- Gravitational waves are **disturbances in the fabric of space-time, arising from incredibly violent and energetic phenomena in the Universe.**
- **Albert Einstein, in his general theory of relativity formulated in 1916, first theorized the existence of these waves.** According to Einstein's mathematical equations, the motion of massive objects undergoing acceleration, such as black holes or neutron stars orbiting each other, would disrupt space-time, leading to the propagation of wave-like distortions in all directions.
- **These cosmic ripples, traveling at the speed of light, carry valuable information about their sources and provide insights into the nature of gravity itself.**
- The **most powerful gravitational waves originate from cataclysmic occurrences like the merging of black holes, the explosive deaths of massive stars known as supernovae, and the collisions of neutron stars.**
- Additionally, gravitational waves can be generated by the irregular rotation of neutron stars, which deviate from perfect spherical shapes, and there are even speculations about the remnants of gravitational radiation from the Big Bang contributing to their production.

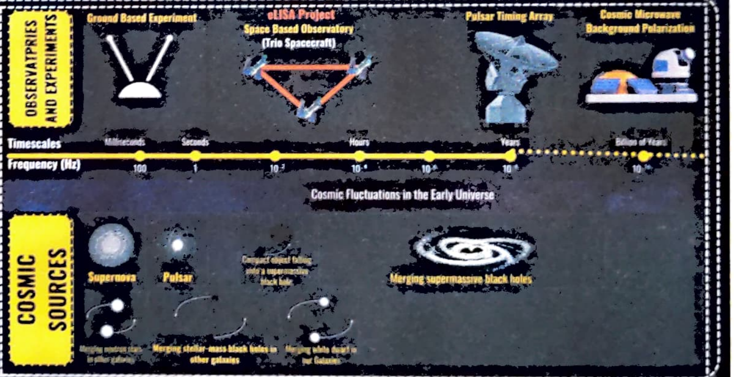


DISCOVERY OF GRAVITATIONAL WAVES

- The **existence of gravitational waves, predicted by Einstein in 1916**, was not confirmed until 1974, two decades after his death.
- **Astronomers Russell Hulse and Joseph Taylor made the groundbreaking discovery using the Arecibo Radio Observatory in Puerto Rico. They observed a binary pulsar, located 21,000 light years away from Earth, which matched the exact system predicted to emit gravitational waves according to general relativity.**
- To test Einstein's prediction, Taylor and his colleagues (Joel Weisberg and Lee Fowler) tracked the radio emissions from the stars and measured how their orbital period changed over time. Within four years, they reported a period change that confirmed the stars were approaching each other at a rate consistent with the emission of gravitational waves as predicted by general relativity.
- The observed rate matched the predicted rate within a remarkable precision of half a percent. In recognition of their discovery and its implications for the study of gravitation, Hulse and Taylor were awarded the Nobel Prize in Physics in 1993 for their identification of a new type of pulsar.
- Astronomers have extensively studied pulsar radio-emissions, which come from neutron stars emitting beams of radio waves. Through these studies, they have observed similar effects that further support the existence of gravitational waves. However, these confirmations have always been indirect or mathematical in nature, lacking direct contact or interaction with an instrument.
- **Everything changed on September 14, 2015, when the Laser Interferometer Gravitational-Wave Observatory (LIGO) physically detected the ripples in spacetime caused by gravitational waves generated by the collision of two black holes located 1.3 billion light-years away.** This landmark event in LIGO's first detection will be remembered as one of humanity's greatest scientific achievements.
- Although the processes that produce gravitational waves are incredibly violent and destructive, **by the time these waves reach Earth, they have become incredibly small, diminishing over vast distances just like the ripples from a pebble dropped in a pond.** In fact, the gravitational waves detected by LIGO were a thousand times smaller than the nucleus of an atom! LIGO was specifically designed to make such unimaginably precise measurements.

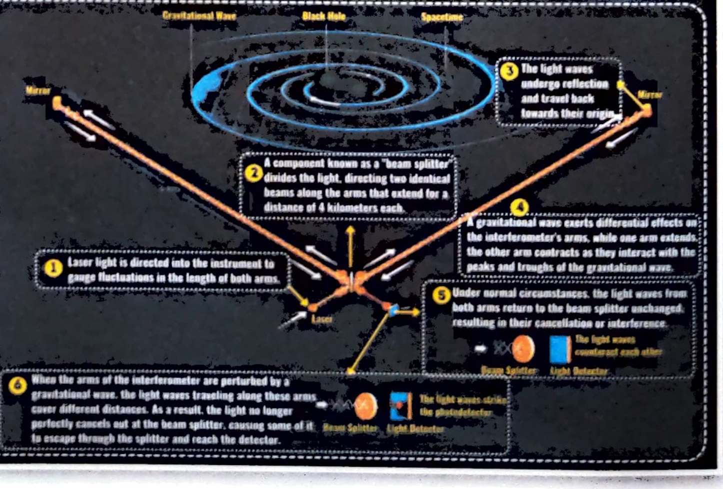
SOURCES OF GRAVITATIONAL WAVES

- Gravitational waves are produced **by any accelerating physical object, including humans, cars, and airplanes.**
- However, the masses and accelerations of such objects on Earth are too small to generate detectable gravitational waves.
- **To detect significant gravitational waves, it is essential to focus on massive objects outside our solar system.**
- The Universe is abundant with immensely massive objects undergoing rapid accelerations, which generate detectable gravitational waves. **These objects include pairs of orbiting black holes or neutron stars, as well as interactions between neutron stars and black holes.**
- Additionally, massive stars exploding at the end of their lives contribute to this phenomenon.
- Astronomers have categorized gravitational waves into four types—**Continuous, Compact Binary Inspiral, Stochastic, and Burst—each associated with a distinct set of gravitational wave signals that researchers can search for in LIGO's data.**


OBSERVATPRIES AND EXPERIMENTS
Ground Based Experiment
eLISA Project
Space Based Observatory
(Trio Spacecraft)
Pulsar Timing Array
Cosmic Microwave Background Polarization
Timescales
Milliseconds
Seconds
Hours
Years
Billion of Years
Frequency (Hz)
100
1
10^{-3}
Cosmic Fluctuations in the Early Universe
COSMIC SOURCES
Supernova
Pulsar
Compact object falling into a supermassive black hole
Merging supermassive black holes
Merging neutron stars in other galaxies
Merging stellar-mass black holes in other galaxies
Merging white dwarf in our Galaxies

WHY DETECT GRAVITATIONAL WAVES?

- **Traditionally, scientists have relied on electromagnetic (EM) radiation to study the Universe.**
- However, they are now exploring other messengers of information, such as neutrinos. Gravitational waves offer a fundamentally different perspective, separate from EM radiation.
- Comparing this to human senses, it is like having only eyes to observe the Universe and then suddenly discovering the ability to hear distant vibrations.
- **LIGO, functioning as a gravitational wave antenna, detects vibrations in space-time itself,** unveiling invisible phenomena like colliding black holes.
- **Gravitational waves travel unhindered, carrying undistorted information about their sources.**
- **These waves originate from incredibly cataclysmic events, like merging neutron stars or the birth of the Universe,** providing unprecedented insights into the previously unseen aspects of the cosmos.
- LIGO's breakthrough has sparked groundbreaking research in physics, astronomy, and astrophysics, unveiling the mysteries of the Universe.



① Laser light is directed into the instrument to gauge fluctuations in the length of both arms.

② A component known as a "beam splitter" divides the light, directing two identical beams along the arms that extend for a distance of 4 kilometers each.

③ The light waves undergo reflection and travel back towards their origin.

④ A gravitational wave exerts differential effects on the interferometer's arms, while one arm extends, the other arm contracts as they interact with the peaks and troughs of the gravitational wave.

⑤ Under normal circumstances, the light waves from both arms return to the beam splitter unchanged, resulting in their cancellation or interference.

⑥ When the arms of the interferometer are perturbed by a gravitational wave, the light waves traveling along these arms cover different distances. As a result, the light no longer perfectly cancels out at the beam splitter, causing some of it to escape through the splitter and reach the detector.

TYPES OF GRAVITATIONAL WAVES

CONTINUOUS GRAVITATIONAL WAVES

Continuous gravitational waves arise from a spinning massive object like a neutron star. Imperfections in its shape generate gravitational waves with a constant frequency and amplitude. If the spin rate remains steady, the emitted waves maintain their characteristics analogous to a sustained musical note. Researchers have simulated the sound of continuous gravitational waves detected by LIGO.

COMPACT BINARY INSPIRAL GRAVITATIONAL WAVES

LIGO focuses on detecting Compact Binary Inspiral gravitational waves, which have been the only objects observed so far. These waves originate from orbiting pairs of dense and massive objects such as black holes, neutron stars, and white dwarfs. The three subclasses are

- Binary Neutron Star (BNS),
- Binary Black Hole (BBH), and
- Neutron Star-Black Hole Binary (NSBH).

As these objects revolve around each other, they emit gravitational waves, gradually spiraling closer due to the energy lost in the process. This continuous inspiral leads to an accelerating and inevitable merger of the objects.

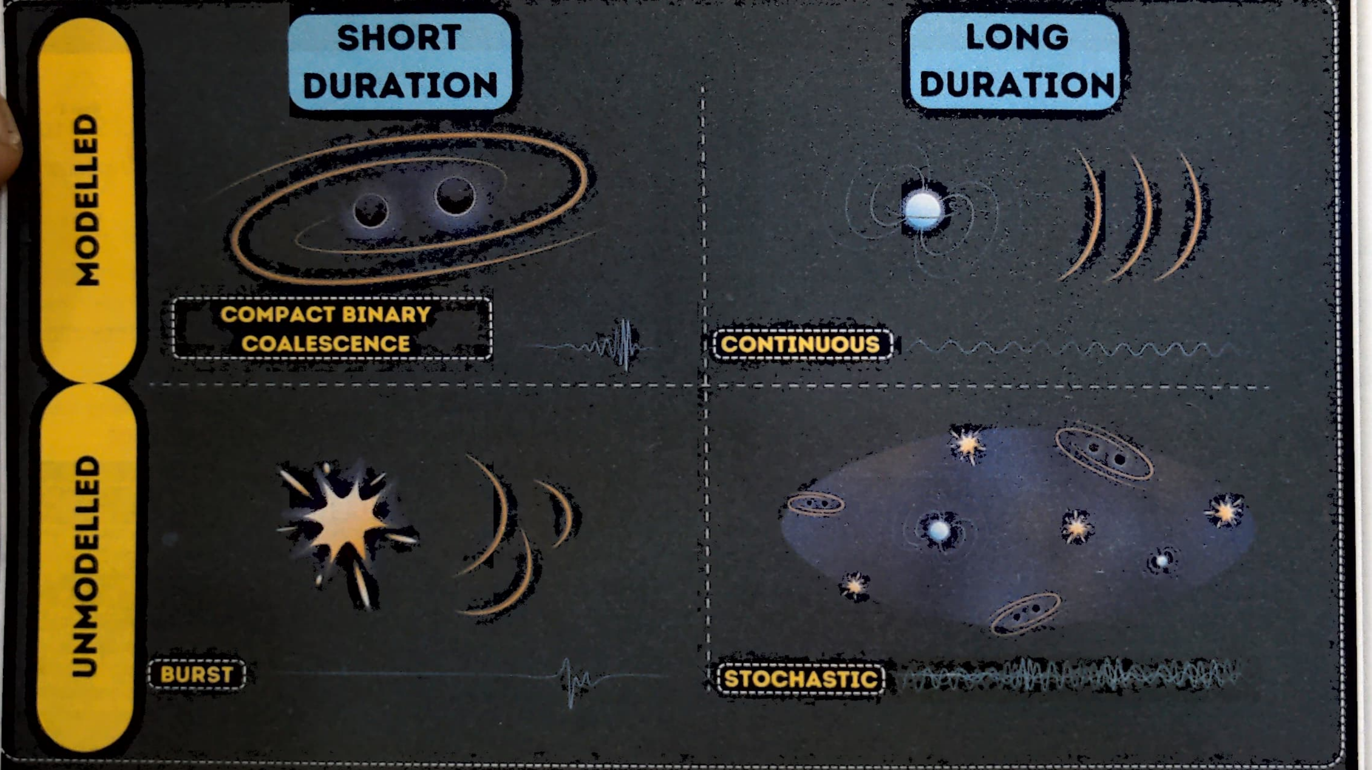
STOCHASTIC GRAVITATIONAL WAVES

LIGO is not concerned about multiple significant gravitational wave sources occurring simultaneously. However, small gravitational waves from all directions create a random pattern known as a "Stochastic Signal." These waves are challenging to detect but may include remnants from the Big Bang. Detecting relic gravitational waves allows us to explore the Universe's history in unprecedented ways.

BURST GRAVITATIONAL WAVES

The hunt for burst gravitational waves is an exploration of the unexpected. LIGO has yet to detect them, and there are numerous unknowns that make predictions challenging. The nature of these waves and their sources remains uncertain, which means we cannot rely on predetermined properties as we do with continuous and compact binary inspiral waves.

In the search for burst gravitational waves, scientists must maintain an open mind and remain receptive to unfamiliar patterns. It requires recognizing signals even when their characteristics have not been previously modeled. While this poses difficulties, detecting burst gravitational waves holds tremendous potential for unveiling groundbreaking insights about the Universe.



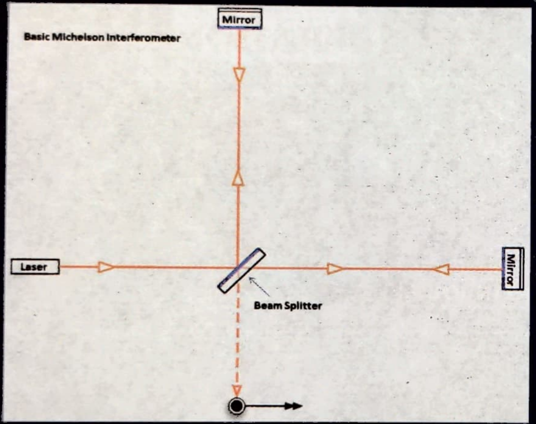
LIGO - A GRAVITATIONAL-WAVE INTERFEROMETER

LIGO, an acronym for **Laser Interferometer Gravitational-wave Observatory**, is an impressive feat of precision engineering and the largest gravitational wave observatory globally. It consists of two immense laser interferometers positioned at a staggering distance of 3000 kilometers from each other. LIGO harnesses the characteristics of light and the fundamental properties of space to identify and gain insights into the sources of gravitational waves (GW).

Advanced LIGO- LIGO has undergone significant changes and upgrades over the years. Initially, there was "Initial LIGO" which operated from 2002 to 2010 as a testbed. Although it didn't detect gravitational waves, it provided valuable insights for improvement. In 2010, Initial LIGO was dismantled to make room for "Advanced LIGO" (aLIGO). Construction and testing of aLIGO took 7 years, from 2008 to 2015. The aim is to make aLIGO 10 times more sensitive than its predecessor.

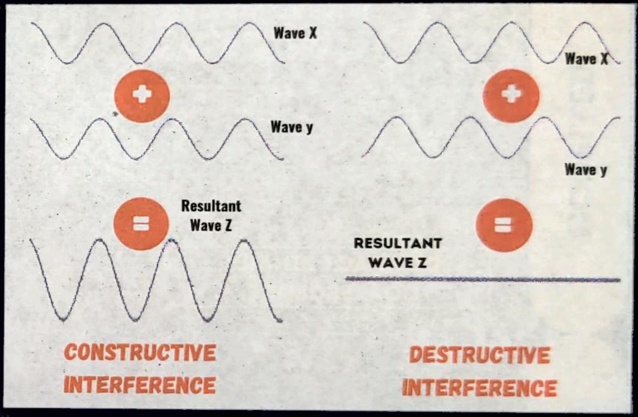
WHAT IS AN INTERFEROMETER?

- Interferometers are versatile tools used in various scientific and engineering fields.
- **They operate by combining light sources to create interference patterns that hold valuable information about the studied object or phenomenon.**
- Interferometers are particularly effective for making highly precise measurements that are otherwise unattainable.
- **LIGO's interferometers, for instance, are designed to detect gravitational waves by measuring distances as small as 1/10,000th the width of a proton.**
- Interferometers were initially developed in the 19th century by scientists like Fizeau, Hoek, Mascart, Airy, and Ketteler to study the wave properties of light and its dependence on different mediums, including the proposed "luminiferous ether."
- **The Michelson-Morley Interferometer, invented by Michelson and Morley in 1887, played a crucial role in disproving the existence of the ether and contributed to the foundation of Einstein's theories of relativity.**
- The Michelson interferometer's configuration, known since the late 1960s, was recognized as ideal for detecting the effects of gravitational waves on space-time. Its precise measurement of light phase changes along perpendicular arms became a fundamental aspect of modern gravitational wave interferometric detectors, including LIGO, Virgo, Geo, and KAGRA.
- The Michelson laser interferometer, utilizes a laser, beam-splitter, mirrors, and a photodetector to capture the resulting interference pattern.



WHAT IS AN INTERFERENCE PATTERN?

- Understanding interference is key to comprehending how interferometers function.
- **Interference occurs when multiple waves intersect and interact, leading to the formation of an interference pattern.**
- For instance, **when stones are thrown into a still body of water, the resulting concentric waves interfere with each other.** This interference can result in larger, smaller, or even no waves at certain points of intersection.
- The principles of interference are straightforward: The heights and depths of interacting waves are added together, producing the interference pattern.
- Total **constructive interference** occurs when **identical waves moving in the same direction perfectly align, resulting in a larger wave.**
- Conversely, total **destructive interference** happens when **identical waves moving in opposite directions align in a way that cancels each other out.**
- Although real-world waves are rarely identical and perfect alignment is rare, the resulting wave at the points of intersection always represents the sum of their heights or depths. In an idealized scenario, two identical waves moving in opposite directions exhibit a range of heights from total constructive interference to total destructive interference. In reality, interacting waves have varying amplitudes and frequencies, resulting in a more complex interference pattern. However, the fundamental principle of adding the heights or depths of the interacting waves at each point remains applicable.



WHAT IS LIGO?

- LIGO, short for **Laser Interferometer Gravitational-wave Observatory**, is a remarkable observatory that **specializes in detecting gravitational waves**. Unlike traditional astronomical observatories, LIGO operates differently in three key aspects:
  - **LIGO does not rely on detecting electromagnetic radiation** like visible light or radio waves. Instead, it detects gravitational waves, which are a distinct phenomenon not part of the electromagnetic spectrum.
  - Unlike optical telescopes or radio dishes, **LIGO does not need to collect light from specific locations in space.** It doesn't have a dish or a focused view. Its detectors consist of long vacuum tubes arranged in an "L" shape, enclosed within protective concrete structures.
  - **A single LIGO detector alone cannot confirm a gravitational wave signal.** Confirmation typically requires multiple detectors to observe the signal simultaneously. The initial discovery of gravitational waves necessitated the detection in both LIGO's Hanford and Livingston detectors. To locate potential light sources associated with gravitational wave detections, ideally, three or more detectors are needed to triangulate the source's position in the sky.
- Despite its differences, LIGO has successfully detected numerous gravitational wave signals, with collaborations between LIGO and other observatories like Virgo contributing to significant discoveries, such as the first binary neutron star merger detection.

LIGO'S INTERFEROMETER

- **At the core of LIGO's interferometers is the Michelson Interferometer design**, which dates back to the 1880s. However, LIGO's interferometers differ significantly from their predecessors in terms of scale and complexity.
- While both Michelson interferometers and LIGO's interferometers are L-shaped, LIGO's instruments are much larger. **LIGO's arms are 4 kilometers (2.5 miles) long, making them the largest interferometers ever built.** In contrast, the original Michelson interferometer had arms of about 1.3 meters in length. The larger size of LIGO is crucial for detecting gravitational waves, as it allows for more precise measurements. LIGO needs to measure changes in distance that are 10,000 times smaller than a proton, necessitating a larger and more sensitive instrument.
- To overcome the limitations of a traditional Michelson interferometer, **LIGO incorporates Fabry-Perot cavities into its design.** These cavities consist of additional mirrors placed in each arm near the beam splitter. The laser light in each arm bounces back and forth between these mirrors, building up intensity and effectively increasing the distance traveled by each laser from 4 kilometers to 1200 kilometers. This extension of the arm length enhances the sensitivity of LIGO to gravitational waves, making them easier to detect.
- In addition to length, laser power plays a crucial role in LIGO's sensitivity. Increasing the power of the laser improves the sharpness of the interference fringes measured by the photodetector. However, generating a laser with the required initial power is impractical. To address this, LIGO incorporates Power Recycling Mirrors. These mirrors reflect the laser light back into the interferometer, boosting the power of the laser beam inside the Fabry-Perot cavities without the need for an extremely powerful laser at the outset. The increased laser power enhances the visibility of the interference fringes, aiding in the detection of gravitational waves.
- LIGO's interferometers also feature signal recycling mirrors, which further enhance the received signal, and advanced vibration damping mechanisms to minimize noise and improve the instruments' ability to detect vibrations caused by gravitational waves. These modifications make LIGO's interferometers unique and capable of making incredibly precise measurements.
- In summary, LIGO's interferometers are based on the Michelson Interferometer design but incorporate Fabry-Perot cavities, power recycling mirrors, signal recycling mirrors, and advanced vibration damping mechanisms. This combination of technologies allows LIGO to achieve the sensitivity and precision required for detecting gravitational waves, making it a groundbreaking observatory in the field of astrophysics.

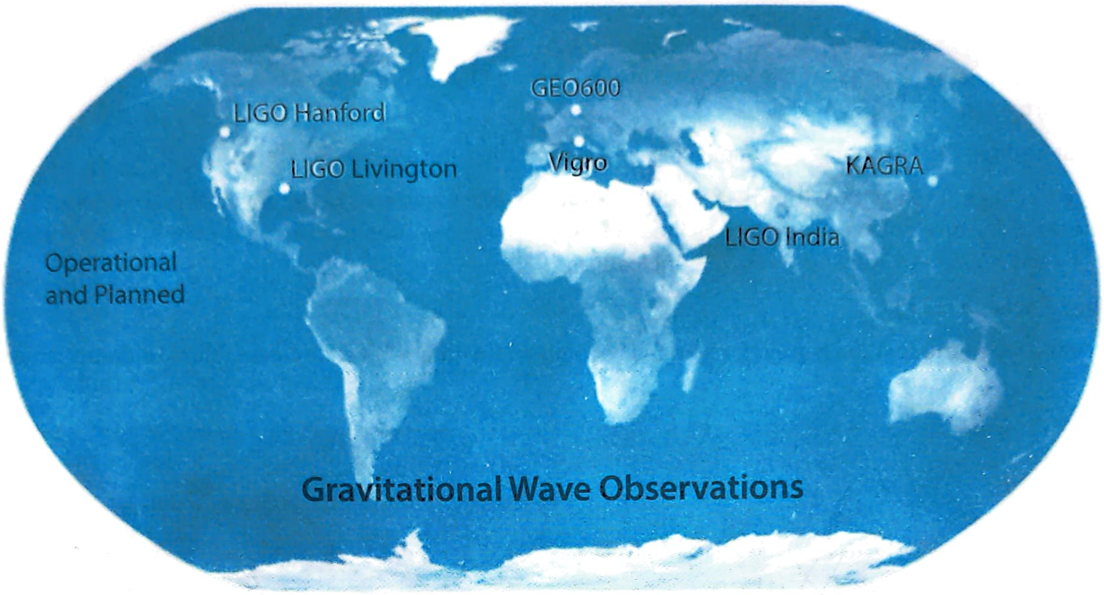


Figure 21.1

Gravitational Wave Observatories

Since 1970, the thought of **space-borne large-scale interferometer** was there and the Laser Interferometer Space Antenna (LISA) idea was originated. Its main aim is the **identification of low frequency gravitational waves which are unreachable from the Earth surface. LISA created by satellites constellation which are 5 × 106 Km apart was an interferometer having shape of an equilateral triangle.**

Better frequency range can be discovered by the Space-borne interferometers than their complement on Earth. Precisely, **eLISA can take gravitational radiation of less than 1 Hz dimensions.**

LIGO detected the **gravity wave which grows from 35 Hz up to 250 Hz.** There are inevitable gravitational noise sources on Earth **in the shape of, weather phenomena, moving objects and seismic motion.** As a result, only high frequency gravity waves will be noticeable while **interferometers in space can escape these noise sources. The bigger the interferometer, the smaller the detectable strain.**

The **mother satellite** flames two Lasik signals which get reflected by the opposite vertex satellites and thereby creating the two interferometer arms. There is no beam splitter in mother **satellite but although it generates two independent phase-locked laser signals. When these signals return to the mother satellite, any present phase shift is registered.**

The **complete arrangement is positioned 20° at the rear of our planet and rotates on an Earth like orbit around the sun** which is nearly 50 million Km far away from the Earth.

There is a requirement of each satellite maintaining a constant distance with respect to the other satellite, if they have to function as an interferometer because every satellite pair is an interferometer arm and it would be ineffective if they changed length (i.e., without the perturbation of a gravitational wave).

LISA: Taking the search for gravitational waves into space

Due for launch in the mid-2030s, LISA (Laser Interferometer Space Antenna) will be the first dedicated space-based gravitational wave detector. LISA will consist of a constellation of three identical spacecraft arranged to form a triangle with 'arms' one million kilometres long.

LISA will work rather like LIGO, which made the first historic detection of gravitational waves, but, with arms 600,000 times longer than LIGO, it will extend our capabilities to 'listen' to new kinds of dark phenomena in the Universe.

The distance between the spacecraft is precisely monitored so that even the tiniest changes in the lengths of the 'arms' caused by a passing gravitational wave can be measured.

LISA Pathfinder

Launched in 2015, LISA Pathfinder paves the way for the LISA mission by testing the concept of a space-based gravitational wave detector in miniature.

It serves as a test bed for the technology by mimicking one arm of the future LISA constellation.

LISA Technology Package (LTP) onboard LISA Pathfinder is a miniature version of one arm of LISA. Instead of three full-size spacecraft separated by one million kilometres, it has two test masses – identical 46 mm cubes – separated by around 40 centimetres. They are housed in individual vacuum enclosures.

LISA Technology Package (LTP)

A laser beam (red) probes the test mass positions and is recombined with a reference beam (blue) to detect any movement.

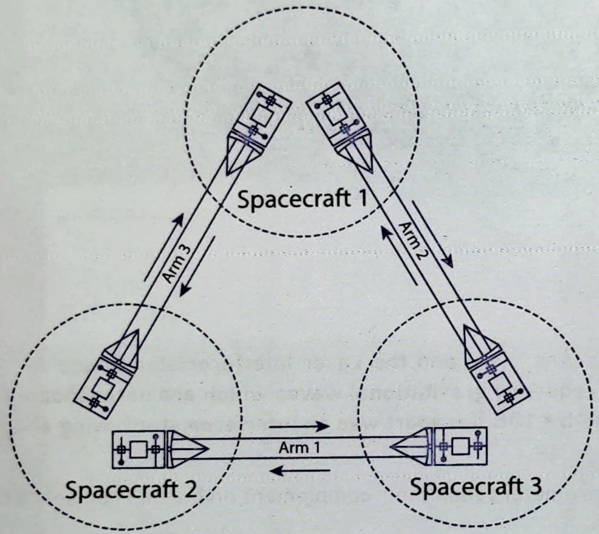


Figure 21.2
Trio Space Craft

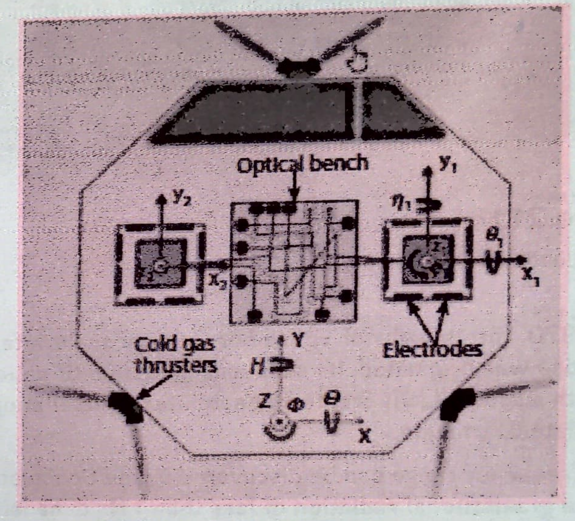


Figure 21.3
Interferometer

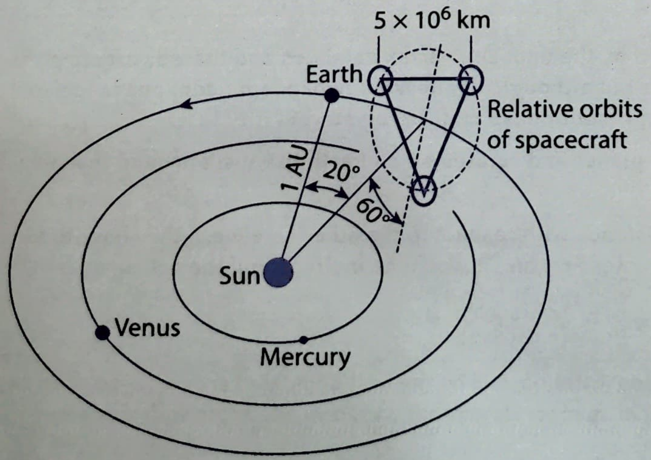


Figure 21.4
Position of All Three Spacecrafts

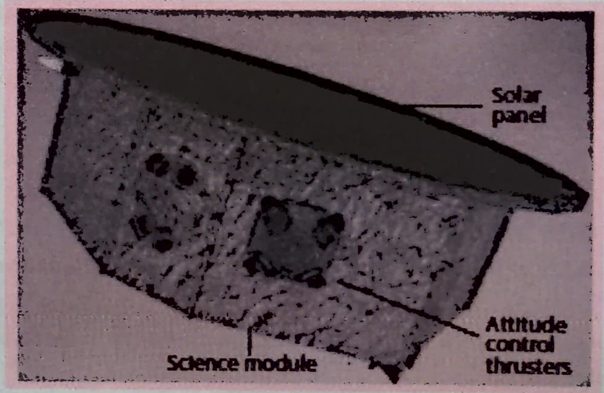


Figure 21.5
Space Craft Outer View

The test masses' movements must only be influenced by gravity so they have to be protected from other forces – such as the pressure of sunlight, magnetic fields, temperature fluctuations and the LISA spacecraft's own gravity.

22.1 CELL

The study of cell is called **cytology**. The study of cell along with metabolic aspects is called **cell biology**.

Cell Theory: **H. J. Dutrochet** (1824) for the first time gave the idea of cell theory. The cell theory was, formulated by two German scientists **M. J. Schleiden** (Botanist) and **T. Schwann** (Zoologist) in 1839. According to cell theory, "cell is the basic structural and functional unit of an organism."

22.2 TYPES OF CELL

On the basis of presence of nucleus, cells are of the following types (**Table 22.1**).

22.2.1 Prokaryotic Cells

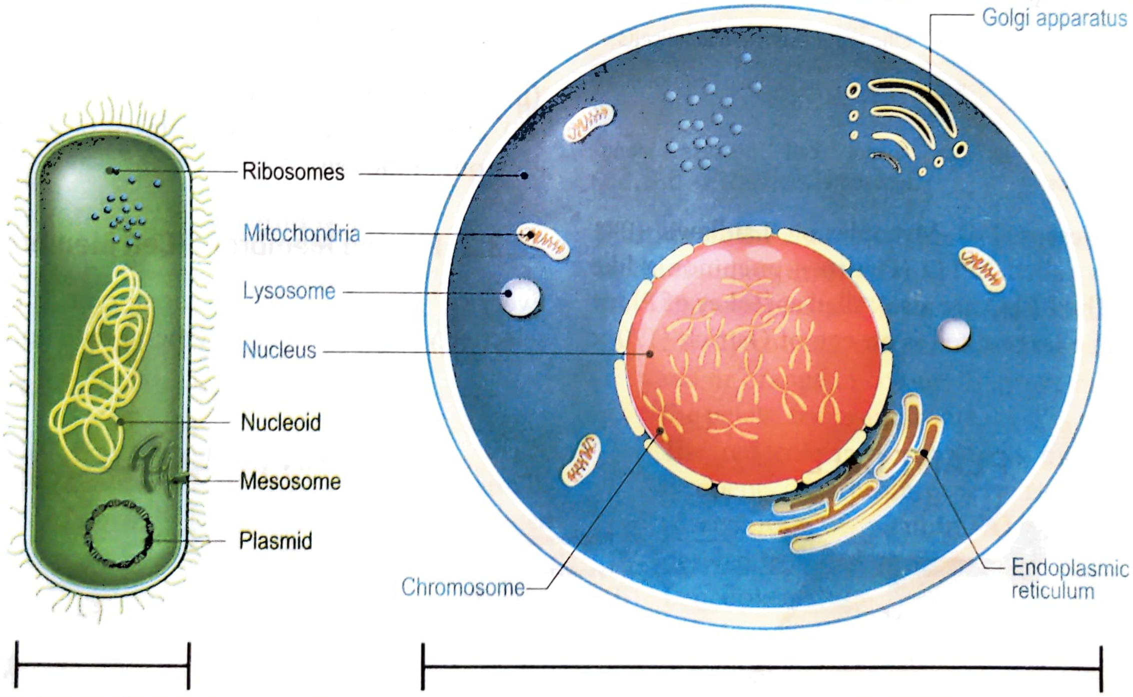
They lack nuclear membrane and nucleolus or a definite nucleus. The primitive nucleus is called a **nucleoid** or incipient nucleus. The cell organelles like mitochondria, chloroplasts, golgi bodies and endoplasmic reticulum are absent. Genetic material is histone-free and made up of double stranded DNA only and is also called a **genophore,** e.g., mycoplasma, bacteria, blue-green algae.

22.2.2 Mesokaryotic Cells

They have definite nucleus and show peculiar type of division called dinomitosis. They lack deoxyribonucleohiston, e.g., Dinoflagellates (a group of algae).

TABLE 22.1 Comparison between Prokaryotic and Eukaryotic Cells

Prokaryotic *vs* Eukaryotic



Prokaryotic cells	Eukaryotic cells
1. Prokaryotic cells are referred to as simple and unicellular (single-celled) organisms.	1. Eukaryotic cells are referred to as complex and multicellular organisms.
2. They lack a nucleus, and do not have any membrane bound organelles.	2. They have nucleus as well as membrane-bound organelles within the cell.
3. The nucleoid of prokaryotic cells contains DNA that is small and circular.	3. The DNA or genetic material of a eukaryotic cell is found within the cell's nucleus.
4. Prokaryotic cells have less cell parts compared to eukaryotic cells, they are DNA, ribosomes, cell membrane, cell wall, there are other cell parts that are not present in all prokaryotic cells.	4. A plasma membrane, cytoplasm, nucleus, ribosomes, mitochondria, peroxisomes, and, in some cases, vacuoles make up a eukaryotic cell, However, there is a distinction between animal and plants.
5. Some examples of prokaryotic cells include Bacteria and Archaea.	5. Examples of eukaryotic cells include animals and plants.

22.2.3 Eukaryotic Cells

They have true or definite nucleus (with nuclear membrane and nucleolus). DNA is associated with histone protein in the chromosomes. Membrane bounded cell organelles such as Mitochondria, Plastids, E.R. and Golgi bodies are present in, e.g., cells of higher organisms like plants and animals.

TABLE 22.2 Comparison between Plant Cells and Animal Cells

Plant Cells	Animal Cells
Possess cell wall.	Does not possess cell wall.
Chloroplasts are present in plant cells.	Animal cell do not possess chloroplasts.
Plant cells are almost rectangular in shape.	Animal cells are round in shape.
Plant cell possess large vacuoles but mostly one in number.	Animal cells have many small vacuoles.
Cilia rarely occur in plant cells.	Cilia are present in animal cells.
Higher plants do not possess centrioles.	Animal cells contain centrioles.
Plant cells have no or less number of lysosomes.	Animal cell possess many lysosomes.

The smallest cell is Mycoplasma Laidlawii (0–1 to 0–3µ), also called PPLO (Pleuro – pneumonia like organisms). The PPLO are also called as **'Joker of Plant Kingdom'**. The largest cell is an egg of Ostrich (170 × 155 mm).

22.3 CELL STRUCTURE

A cell consists of various components. They are briefly described below.

22.3.1 Cell Wall

The plant cells have a definite and rigid cell wall. The most striking difference between plant and animal cells is the absence of cell wall in the animal cells. Cell wall is dead and permeable (**Table 22.2** and **Figure 22.1**).

Middle Lamella is the cementing layer between two cells which consists of mainly pectic substances (Ca pectate and some Mg pectate). During maturation of fruits the pectic substances in the middle lamella become soluble due to the activity of pecteolytic enzymes; hence ripe fruits become soft.

Functions

(i) The cell wall represents the exoskeleton of cell and provides mechanical strength to cell.
(ii) Cell wall provides a definite shape to plant cell.
(iii) It is involved in the movement of material in and out of the cell.

22.3.2 Plasma Membrane/Cell Membrane

Every cell is enclosed by cell membrane. It is living and selectively permeable. In cell membrane lipids are 40%,

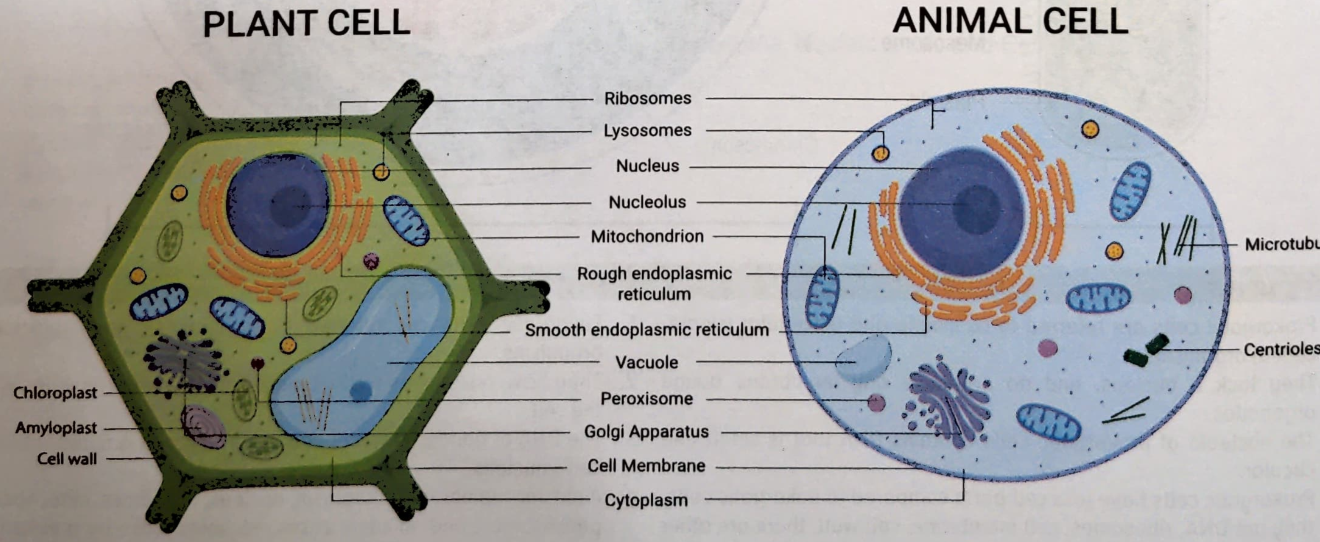


Figure 22.1
Pictorial view of Plant and Animal Cell

protein 52% and carbohydrates (oligosaccharides) are in least proportion (5 to 8%).

Functions

(i) **Endocytosis and exocytosis:** Macro-molecules are ingested into the cell from outside through **endocytosis,** which includes both **phagocytosis** (when solid particles are ingested) and **pinocytosis** (when fluid droplets are ingested), and are secreted out from the cell through **exocytosis.**

(ii) **Passive transport:** (diffusion and facilitate transport). In passive transport movement of molecules or ions is from high to low concentration in a chemical gradient or in an electrochemical gradient.

Active transport and ATP-linked systems: The basic difference between active transport and facilitated transport is that the active transport allows transport against a concentration gradient; such that the cells can obtain considerable quantities of certain metabolites even when they are present at a very low concentration in the surrounding medium.

22.3.3 Endoplasmic Reticulum (E.R.)

It is network of delicate strands and vesicles in the cytoplasm. E.R. extends from nucleus throughout the cytoplasm in the form of flattened sacs or cisternae, which are surrounded by double unit membrane.

E.R. may be

(A) **Rough or Granular E.R.:** It bears ribosomes on its surface. It is mainly found in cells actively engaged in protein synthesis.

(B) **Smooth or Agranular E.R.:** It does not bear ribosomes on its surface. This type of E.R. is associated with **lipid** and **steroid** synthesis. It also helps in cell detoxification.

Functions

(i) It provides internal support to cytoplasm or form endoskeleton or cytoskeleton of the cell.
(ii) It helps in the intracellular transport of substances.
(iii) It takes part in the synthesis of lipo-protein and glycogen.
(iv) Rough E.R. helps in protein synthesis.
(v) Smooth E.R. helps in steroid or lipid synthesis.

22.3.4 Golgi Complex

Golgi apparatus is also known as dictyosome, golgiosome, idiosome or lipochondria. In plant cells the golgi complex consists of many unconnected units known as **dictyosomes.**

Chemically golgi complex is made up of protein (65–75%), phospholipids (25–30%) and some enzymes such as galactosyle transferase, thiamin pyrophosphatase, and adenosine diphosphatase.

Functions

(i) Synthesis of carbohydrates such as cellulose and hemicellulose.
(ii) Formation of acrosome.
(iii) Formation of lysosomes (secretion of lysosomal enzymes). That is why they are abundant in secretory cells.
(iv) Synthesis of cell plate and cell wall.
(v) It plays a major role in glycosidation of lipids and proteins (synthesis of glycolipids and glycoproteins).

22.3.5 Plastids

Plastids are the characteristics of plant cells. Plastids can be divided into three groups:

(A) **Chromoplasts:** They are pigmented plastids. They mostly contain carotenoids. They may be yellow, red or orange in colour. They are mostly found in the petals, fruits and roots.

The red colour of tomato is due to carotenoid lycopene. Carrots are very rich in β carotene (derivatives of vitamin A). Chromoplasts are derived from chloroplast.

(B) **Leucoplasts:** They are colourless plastids and are mostly found in the plant parts which are not exposed to the light. On the basis of nature and function leucoplasts are of following types:

(i) **Amyloplasts:** Store starch
(ii) **Elaioplasts:** Store fats or oils
(iii) **Aleuroplasts or proteinoplasts:** Store protein

(C) **Chloroplast:** Chloroplast is the largest cell organelle, and is commonly found in eukaryotes and absent in prokaryotes. The chloroplasts are bounded by double unit membrane. DNA which present in chloroplasts or plastids is called **Plastidome.**

Function: Photosynthesis.

22.3.6 Mitochondria

Mitochondria are present in aerobic organisms only and are absent in bacteria and blue green algae (prokaryotic). Mitochondria are generally rod shaped. Mitochondria are surrounded by two unit membranes. **Nass and Nass** discovered the presence of DNA in mitochondria. About 60–70% enzymes have been found in mitochondria (the largest amount). Mitochondria are semi-autonomous bodies. So referred as 'cell within the cell' (genetically autonomous). Mitochondria are commonly called as **powerhouse of the cell**, as the energy rich compounds (ATP) are formed by them.

Function: Aerobic respiration.

22.3.7 Ribosomes

Ribosomes are present in all plants and animal cells. Ribosomes are the smallest cell organelles. These are ultra microscopic structures. Their presence was revealed by electron microscope. These are amembranous (without membrane) cell organelles. In eukaryotic cells they are either free in cytoplasm or attached to outer membrane of E.R. through **ribophorins** (glycoproteins) by their larger subunit 60S. Ribosomes are negatively charged particles. They are made up of ribonucleoprotein. In the cytoplasm they are present in groups called as **polysome or polyribosome.** On the basis of sedimentation value, ribosomes are of two types:

(i) **70S ribosomes:** e.g., bacteria, blue green algae (prokaryotic cells) and cell organelles such as chloroplasts and mitochondria. They consist of smaller subunit 30S and larger subunit 50S.

(ii) **80S ribosomes:** e.g., eukaryotes. They consist of smaller subunit 40S and larger subunit 60S.

The ribosomes contain 40–60% of rRNA (ribosomal RNA) and 30–60% proteins with Arginine and lysine.

Functions: They are the seats of protein synthesis (protein factories).

22.3.8 Lysosomes

These are single membrane bound cell organelles. They are mostly found in animal cells and rarely in plant cells. Lysosomes contain hydrolytic or digestive enzymes (about 36 enzymes), e.g., Glycosidases, Phosphatases, Lipases, Nucleases and Proteases. These enzymes are capable of lysis of cells, so lysosomes are known as **suicidal bags** or lytic bodies of the cells. The hydrolytic enzymes are active at acidic pH (pH-5).

Tay-Sachs disease and **Niemann-Pick disease** of human brain are caused by lysosomes. These diseases are due to the lack of certain enzymes which could digest the sphingolipids.

Functions

(i) Digestion of extracellular substances (Exocytosis).

(ii) Digestion of intracellular substances (Endocytosis).

(iii) Autophagy or cellular digestion. So they are known as cellular scavengers.

Serious genetic diseases like **Hurler's disease** (bones are deformed) is the result of accumulation of glycosaminoglycan (mucopolysaccharide) in lysosomes because the patients suffering from this disease do not have the hydrolytic enzyme α-L-iduronidase in their lysosomes.

22.3.9 Vacuoles

Mature plant cells have one and large-sized vacuole but animal cells have small and many in numbers.

The watery fluid enclosed in the vacuole is called cell sap. A vacuole is fluid-filled sac bounded by a single membrane called the tonoplast (unit membrane).

Cell sap contains water (mainly), mineral salts, sugars, organic acid, oxygen, carbon dioxide and pigments (anthocyanin) as well as some wastes and secondary products of metabolism.

Vacuoles are osmoregulatory in function. Most of the water in mature plant cells occurs in the vacuoles.

22.3.10 Nucleus, Chromosome, Nucleic Acids and Cell Division

22.3.10.1 Nucleus

Nucleus is the controlling centre of the cell. **Robert Brown (1835)** recognised a spherical body, an important biological entity and termed it as **nucleus.** Nucleus consists of following parts:

(A) **Nuclear membrane:** It is the outermost layer of nucleus.

(B) **Nucleolus:** Nucleolus mainly consists of rRNA (ribosomal RNA) and proteins.

(C) **Nucleoplasm:** It is proteinaceous substance. It contains enzymes such as DNA and RNA polymerase and ribosomes.

(D) **Chromatin network:** The thread like chromatin fibres are embedded in nucleoplasm. During cell division, these chromatin fibres break into chromosomes.

Significance of nucleus: Hammerling demonstrated the role of nucleus in heredity.

22.3.10.2 Chromosomes

The haploid set or basic set of chromosomes in diploid organisms is described as **genome.** Usually the gametes contain only one copy of each chromosome. The somatic cells of most organisms contain two sets of chromosomes (a pair of each homologous chromosome).

Minimum number of chromosomes in plants is 2n = 4 in *Haplopappus gracilis* (Asteraceae), Maximum number of chromosomes in plants is 2n = 1262 in *Ophioglossum* (fern).

Minimum number of chromosomes in animals is 2n = 2 in Ascaris, Maximum number of chromosomes in animals is 2n = 1600 in *Aulacantha.*

When chromosomes or chromatin materials are stained with **Orcein** or **Acetocarmine** at prophase two regions become differentiated.

(i) **Euchromatin:** It is light stained region. It is active part of chromatin which helps in RNA synthesis.

(ii) **Heterochromatin:** Darkly stained region as heterochromatin, it is inactive and late replicating.

Structure of chromosome

In chromosomes, DNA and histone are bounded to form **deoxyribonucleoprotein.** The most accepted model for the arrangement of DNA and histone protein is **Nucleosome** model. The term nucleosome was given by **P. Outdet (1975).**

Functions: The specified function of chromosome is to carry the genetic information from one generation to another generation.

22.3.10.3 Nucleic Acids

Nucleic acid (DNA) was first isolated in 1868 by a Swiss scientist **Friedrich Miescher,** from the nuclei of pus cells. He called it **nuclein.** Nucleic acids are made up of the following three components:

(A) **Nitrogenous bases:** They are of two types:

(i) **Purines:** They are dicyclic in nature, e.g. Adenine **(A)**, Guanine **(G)**

(ii) **Pyrimidines:** They are monocyclic, e.g. Thymine **(T)**, Cytosine **(C)**, Uracil **(U)**

(B) **Sugars:** They are also of two types:

(i) Deoxyribose sugar

(ii) Ribose sugar

(C) **Phosphoric acid:** H_3PO_4

Nucleosides: Nucleoside is formed by purine or pyrimidine nitrogenous bases and sugar.

Nucleotides: In a nucleotide purine or pyrimidine nitrogenous base is joined by deoxyribose sugar or ribose sugar, which is further linked with phosphate group to form nucleotide.

Polynucleotides: Nucleic acids are **polynucleotides. A number of nucleotides join through phosphodiester bond** and form polynucleotide.

22.3.10.4 Structure of DNA

DNA is mainly localised in nucleus as the part of chromosomes (DNA protein complex is called chromatin).

Of the total amount of DNA in plant cell, 90% occurs in nucleus (in chromatin), 8% in mitochondria and 0.5 to 2.0% in chloroplasts, hence cytoplasmic DNA is 1–10% (**Figure 22.2**).

Wilkins and **Franklin** in 1952 for the first time (on the basis of X-ray diffraction studies) indicated double helical structure of DNA. In 1953, **J. Watson** and **F.C. Crick** gave the double helical model of DNA. **Watson, Crick** and **Wilkins** in 1962 got Nobel Prize for the structure of DNA.

(i) The amount of adenine is always equal to that of thymine and the amount of guanine is always equal to that of cytosine (i.e., A = T and G = C).

(ii) The amount of purine and pyrimidines are equal (i.e., A + G = T + C).

(iii) The ratio of A + T / G + C is not constant or may vary from one species to another. In higher plants and animals A + T and G + C ratio is 1.40:1 and in viruses, bacteria and lower plants A + T and G + C ratio is 0.6:1.

(iv) Purines need much space while pyrimidines occupy little space.

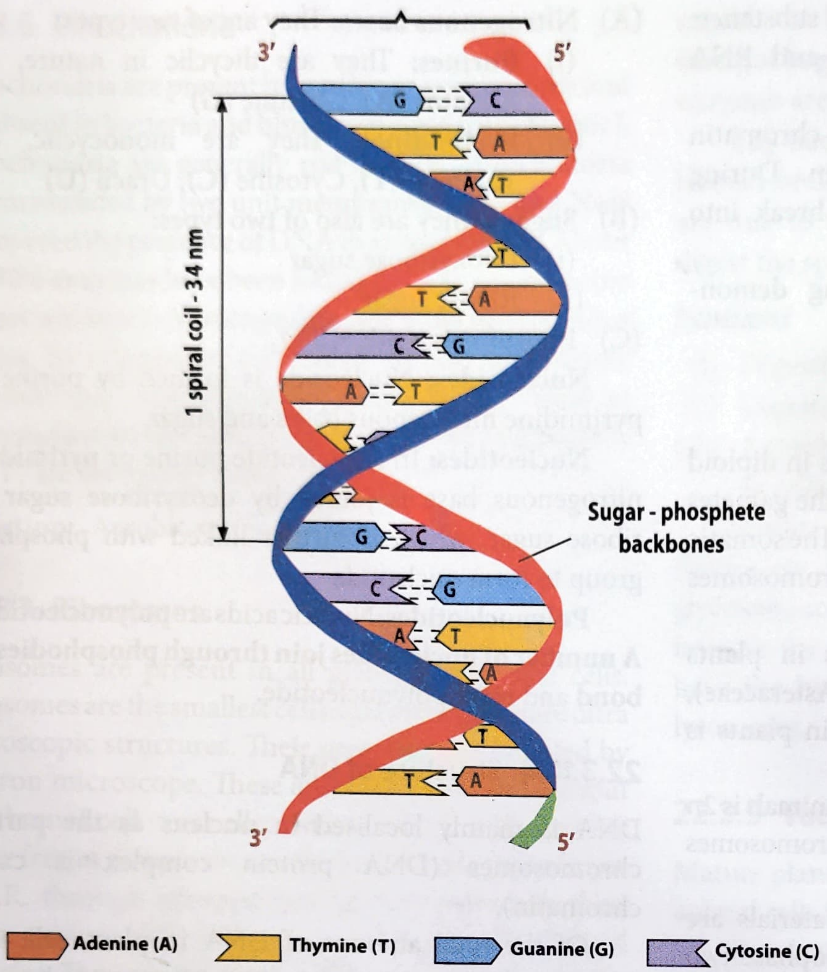


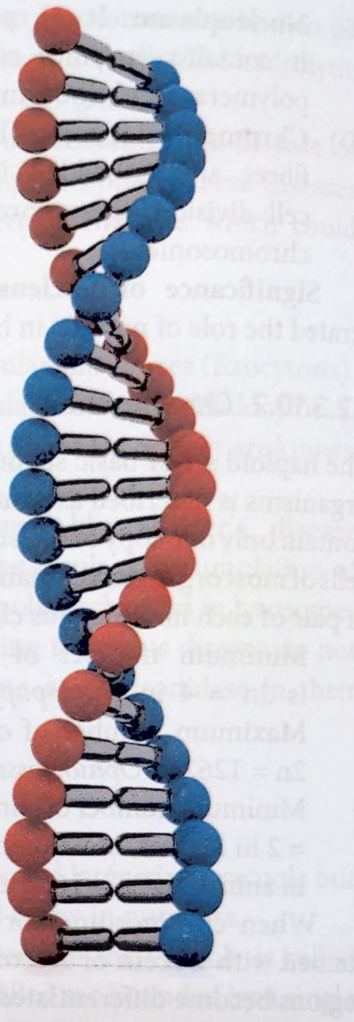
Figure 22.2
DNA Structure

The bases of two chains are linked together by H_2 bonds which are necessary to stabilise the double helical structure.

Adenine–thymine pair has two hydrogen bonds and guanine–cytosine pair has three hydrogen bonds. If one strand has adenine another would have thymine. So, the two strands are known as complementary strands. These complementary strands show that sugar molecule in one strand is in upward direction while the sugar molecule in another strand is in downward direction. Such a condition is known as antiparallel. Thus two strands of DNA are **complementary** and **antiparallel.**

DNA molecule consists of two right-handed long chains in the form of a double helix with a diameter of 20 Å.

The double helix makes a turn after every 34 Å. Generally, a turn has 10 nucleotides or 10 base pairs. So, the distance between two base pairs is 3.4 Å.



The DNA is mostly right-handed, i.e., B-DNA, and the DNA with left-handed coiling is called **Z-DNA** (**Table 22.3**).

TABLE 22.3 The Difference between B-DNA and Z-DNA

B-DNA	Z-DNA
1. The helical coiling is right-handed.	1. The helical coiling is left-handed.
2. The length of one turn is 34 Å which contains mostly 10 nucleotides.	2. The length of one turn is 45 Å which contains mostly 12 nucleotides.
3. Distance between two nucleotides is 3.4 Å.	3. Distance between two nucleotides is 3.7 Å.
4. Repeating unit is a mononucleotide.	4. Sugar residues have alternating orientation, so the repeating unit is a dinucleotide.
5. Diameter is 20 Å.	5. Diameter is 18 Å.
6. The angle of twist per repeating unit is at 36°.	6. The angle of twist per repeating unit is at 60°.

22.3.10.5 RNA (Ribonucleic Acid)

RNA is the polymer of ribonucleotides. These nucleotides join together to form single-stranded RNA. RNA was the first nucleic acid of this planet. There are different types of RNA:

(A) **Messenger RNA (mRNA):** The term mRNA was given by **Jacob** and **Monod** (1961). It carries genetic information from DNA to ribosomes where protein synthesis occurs under its direction. It is 5 to 10% of the total RNA.

(B) **Transfer RNA (tRNA) or soluble RNA (sRNA):** It is about 10–20% of the total RNA. The molecules are smallest (having 75 to 80 of ribonucleotides). It is responsible for carrying amino acid molecules to the site of protein synthesis. **Holley** described the molecular structure of yeast alanyl tRNA and shared Nobel Prize with **Nirenberg** and **Khorana** in 1968. The molecular model of this tRNA is popularly known as **clover-leaf model**. The main function of IRNA is selection of correct codon and amino acid, The 5’ end of tRNA always ends in the base guanine while the 3’ end always ends in the base sequence CCA. The nucleotide sequence of the rest of the molecule is variable. The amino acids are attached to CCA end or terminus.

(C) **Ribosomal RNA (rRNA):** It consists of about 80% of the total RNA. It is the most stable type of RNA. Molecular weight is 12,00,000. Ribosomes consist of 65–80% of rRNA.

Functions

(i) The mRNA carries information from nucleus to cytoplasm in the form of codons.
(ii) The rRNA gives site for the attachment of mRNA.
(iii) The tRNA carries amino acids up to the site of ribosomes.

TABLE 22.4 **The Difference between DNA and RNA**

DNA	RNA
1. Double-stranded structure.	1. Single-stranded structure.
2. The sugar is Deoxyribose type.	2. The sugar is Ribose type.
3. DNA is always genetic.	3. RNA is mostly non-genetic.
4. The pyrimidine bases are cytosine and thymine.	4. The pyrimidine bases are cytosine and uracil.

22.3.10.6 Replication, Transcription, Reverse Transcription and Translation

DNA to DNA formation is called replication or duplication. The formation of mRNA from DNA in the presence of RNA polymerase enzyme is described as **transcription**. However, the formation of DNA upon RNA template was discovered by **Temin** and **Baltimore.** That is why this process is called **teminism** or **reverse transcription.** In this way all these three RNAs help in protein synthesis. The formation of protein (polypeptide chain) at the site of ribosomes is called **translation.**

22.3.10.7 Gene

Johanson (1909) coined the term ‘gene’. Johanson described gene as “unit of heredity”. The genes are located on chromosomes. One chromosome has one DNA. A specific DNA base pair sequence those are responsible for the formation of specific protein is called gene. All characteristics of human body are an expression of certain protein. Genes have full control over protein synthesis and are responsible for hereditary characters those are going from generation to generation.

S. Benzer has proposed the following different terms to explain different aspects of gene on the basis of functional activities:

(A) **Cistron:** It is the functional unit of DNA chain. It is also called as structural gene.
(B) **Recon:** It is the unit of recombination.
(C) **Muton:** It is the unit of mutation.

The gene is the part of DNA. The artificial synthesis of gene was done by **H.G. Khorana.** This gene was of yeast alanyl tRNA and made up of 77 nucleotide pairs.

Jumping or Motile or Floating genes: These genes were discovered by **Barbara McClintock** in corn. For this brilliant work **McClintock** was awarded Nobel Prize in 1983. The term **transposon** was used for “jumping genes” by **Hedges** and **Jacob**. The jumping genes change their position on the same chromosome and also move from one chromosome to the other.

Pleiotropic gene: Single gene which controls the expression of more than one character is called **pleiotropic gene.**

22.3.10.8 Genetic Code

The term genetic code was given by **George Gamow.**

The sequence of nitrogen bases on the mRNA which stores information for linking the amino acids in a definite sequence during synthesis of proteins is called genetic code.

There are 64 triplets (4 × 4 × 4 = 64) of nitrogen bases (codons) and 20 amino acids for protein synthesis (**Figure 22.3**).

The first clue to codon assignments came when **M. W. Nirenberg** and **J. H. Mathai** synthesised mRNA using only uracil, so that all along the length of mRNA, there was no other base and the only possible triplet was UUU. When such a poly-U (RNA) was used in cell free synthesis of polypeptide, only polyphenyl-alanine was synthesised, meaning that the only amino acid coded was phenylalanine. So, it was concluded that triplet UUU coded for the amino acid **phenylalanine**. This news that the genetic code had been cracked appeared in newspapers in 1961. Subsequently, poly AAA gave **polylysine** and poly CCC to **polyproline.** Thus, the following three codons could be assigned, using homopolymers of RNA UUU-phenylalanine, AAA-lysine, CCC-proline.

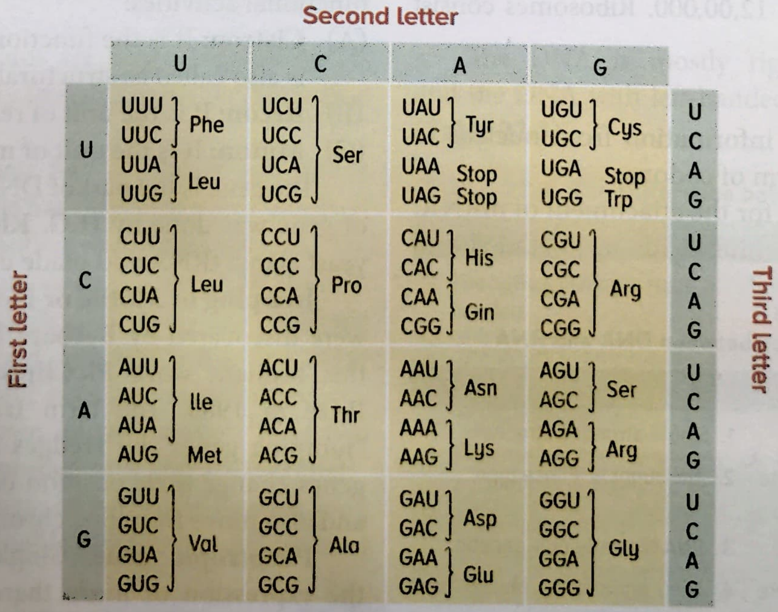
After getting success with homopolymers, **Nirenberg** and co-workers used co-polymers (RNA synthesised by two or more bases) and worked out about 45 codes using AA-tRNA binding technique.

H.G. Khorana, using synthetic DNA prepared polynucleotides with known repeating sequences, e.g., CU CU CU CU CU CU CU = CUC / UCU / CUC / UCU (co-polymers of repetitive sequences). It produced only two amino acids Leucine/Serine in alternating sequence.

It helped in deciphering the code.

Features of Genetic Code / Codon

1. The code is **triplet** (a group of three bases).
2. **Starting codon (Initiation Codon)** is AUG (for methionine amino acid) or rarely GUG: Protein synthesis starts from this codon on RNA during translation.
3. **Termination or non-sense codons** are UAA (Ochre), UAG (Amber), UGA (Opal): Translation process stops with this codon.
4. The **degeneracy of codons**: An amino acid can be coded by more than one codon.
5. **Universality of codons**: Genetic codon is universal meaning it is same in every organism except in some cases.
6. **Comma less codons**: No comma used between two codons.



Second letter

First letter	U	C	A	G	Third letter
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
	UUA Leu	UCA Ser	UAA Stop	UGA Stop	A
	UUG Leu	UCG Ser	UAG Stop	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
	CUC Leu	CCC Pro	CAC His	CGC Arg	C
	CUA Leu	CCA Pro	CAA Gin	CGA Arg	A
	CUG Leu	CCG Pro	CGG Gin	CGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
	AUA Ile	ACA Thr	AAA Lys	AGA Arg	A
	AUG Met	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
	GUC Val	GCC Ala	GAC Asp	GGC Gly	C
	GUA Val	GCA Ala	GAA Glu	GGA Gly	A
	GUG Val	GCG Ala	GAG Glu	GGG Gly	G

Figure 22.3

Genetic Dictionary

7. **Non-overlapping codons:** One base cannot participate in the formation of more than one codon.
8. The code is **non-ambiguous:** Thus one codon cannot specify more than one amino acid.

22.3.10.9 Cell Cycle

It consists of interphase and M-Phase (cell division).

(A) **Interphase:** It is resting phase but nucleus is metabolically most active. It is the **regulatory phase** and **control phase** of cell cycle.

(B) **M-Phase:** It is a **cell division phase** or **response phase** in cell cycle. It is of two types:

(1) **Mitotic division or Mitosis:** The term mitosis was given by **W. Flemming.** Mitotic division occurs in somatic or vegetative cells. The two daughter cells, which are formed are identical to their parents. The chromosome number remains same in the daughter cells.

Significance of mitotic division

(1) It helps in growth and development.

(2) **Meiotic division or Meiosis:** The term meiosis was used by **Farmer and Moore.** It occurs in reproductive or germ cells. Four haploid cells are produced after this division which are not identical to their parent cell. The chromosome number is reduced to half. Meiosis includes two nuclear and one chromosome division.

Significance of meiotic division

(1) It is responsible for recombination of characters in the progeny due to crossing over.

(2) It maintains the original number of chromosomes or constant number of chromosomes.

Colchicine, an alkaloid isolated from Colchicum autumnale (liliaceae) is used in plant breeding for inducing polyploidy. It inhibits or interferes in the formation of spindle fibres and cell plate formation.

Sometimes there is replication of DNA as well as the chromosome but no division of nucleus, so the somatic number of chromosomes in nucleus is increased. This process is called as **endopolyploidy** or **endomitosis** or **c-mitosis**. Endopolyploidy can be induced by colchicine chemical.

X-rays and UV rays inhibit or retard cell division. Antibiotics, e.g., chloromycetin, tetracyclin, puromycin, block cell division and interfere with protein synthesis.

PART–(A) CONCEPTS OF BIOTECHNOLOGY

23.1 ORIGIN AND DEVELOPMENT

Biotechnology is the use of biological system (microbes, plants and animals) and the technique to produce substances, which are beneficial to people. It includes the manufacture of antibiotics, vitamins, vaccines, plastics, etc.; disposal of toxic waste using bacteria, pollution control and production of new fuels. Various techniques deployed in biotechnology are genetic engineering or recombinant DNA technology, hybridism technology, cell and tissue culture, protoplasm fusion. Others can be germplasm development, embryo transfer technology, enzyme and protein engineering, fermentation, bioconversion and immobilisation of cells and cellular products. On the basis of level at which the transfer is made, biotechnology can be classified into two types: gene biotechnology involving gene transfer and non-gene biotechnology involving cells, tissue or the whole organism.

Through hybridisation, biotechnology introduced with improved process genetic varieties of plants and animals from 5000 BC. During 1970s, Norman Borlaug (The Nobel Laureate 1970), an American agriculturist, significantly contributed towards increasing supply of food through various techniques such as hybridisation, selective breeding and gene transfer. The term Hybridisation refers to the technique or method involving crossing two or more individuals having opposite sex of various species with desirable characters. This is undertaken for producing off-springs of mixed character (improved variety). Indian Scientist, Dr. M.S. Swami Nathan (1967) started and developed technologies for raising the country's food production. Hence, he earned the name 'Father of Economic Ecology', through his valuable efforts in this field.

In 1960, another important discovery was made by Werner Arber in 1960 in the form of enzymes known as Restriction Enzyme in bacteria. These enzymes were advantageous as they could slice the organism's DNA strand at a particular point. Moreover, in the year 1973, Stanley Cohen and Herbert Boyer successfully removed a particular gene from a bacterium and placed it into another bacterium using this enzyme. This resulted in formation of Recombinant DNA Technology or generally termed as Genetic Engineering. By using genetically engineered bacteria, later, the scientists successfully produced Human Insulin in 1978, being the market's first biopharmaceutical product for controlling *Diabetes Mellitus.*

23.2 BIOTECHNOLOGY IN INDIA

From ancient times, people used microorganisms in various applications and uses such as improving a variety of plants, fermentation products, curd formation, etc. With time, gradually, the scope of biotechnology expanded. It also enabled to develop crops that can withstand the harsh weather conditions. This, in turn, greatly helped the poor farmers to retain their yield and the government to retain the revenue from it, simultaneously ensuring food security. India, with a large population, offers a huge market for the products and services, taking advantage of these opportunities over many other countries of the world. India's remarkable demographic nature has formed roughly an ideal environment for making the biotech companies to shift their bases to the country.

23.2.1 Department of Biotechnology (DBT)

In 1986, a separate Department of Biotechnology (DBT) was established under the Ministry of Science and Technology to promote the development of the field of modern biology and biotechnology in the country. Several research and development projects, demonstrations and creation of infra-structural facilities are directly or indirectly based on this field. The department has contributed significantly to the growth and application of biotechnology in the areas of agriculture, health care, animal sciences, environment and industry.

23.2.2 Advisory Committees

The two apex level committees functioning with the department are advisory in nature. They are the Scientific Advisory Committee - DBT (SAC-DBT) and the Standing Advisory Committee Overseas (SACO). The committees suggest new areas, assist in priority setting and review monitoring of large inter-institutional, inter-disciplinary projects.

23.3 INITIATIVES AND EFFORTS OF CENTRAL GOVERNMENT OF INDIA IN BIOTECHNOLOGY

Even at the early stage, the Government of India realised the calibre and benefits of this industry and hence, the Department of Biotechnology was established in 1986. It has been established as a central agency, accountable for R&D activities policy, promotion and for international cooperation and manufacturing activities. A big boost has been provided to the biotech industry in India through the initiatives taken by both Central and State governments. Following are some important steps taken by the Government of India:

- Enhancing the expenditure in giving the industry financial support and also establishing a venture capital fund for supporting small and medium enterprises.
- For the approval of Genetically Modified (GM) crops and recombinant DNA products, good regulatory framework has been set up.
- In order to make the Drugs and Cosmetics Act more compatible with international standards, the government has decided to make changes to the Act.
- The country's Patents Bill, passed by the Parliament, allows a 20-year patent term, which is in line with the WTO and TRIPS provisions.
- A widely acknowledged framework of bio-safety guidelines for performing, evaluating, monitoring and releasing genetically engineered organisms. Currently, there are more than 106 institutional biosafety committees.

23.4 APPLICATION OF BIOTECHNOLOGY

Biotechnology has vast applications but the major areas are medical, agricultural, industrial and environmental. The specific applications including general applications of biotechnology can be categorised as follows:

(a) **Genetic Engineering:** Stanley Cohen and Herbert Boyer (1973) conducted an experiment, where they removed a particular gene from a bacterium and placed the same gene into another bacterium. This led to the evolution of Recombinant DNA technology, which is also called as Genetic Engineering. The organisms so formed with altered genetic makeup, with the help of DNA recombinant technology or genetic engineering, are known as Genetically Modified Organisms or GMOs. Transgenic Organism is an organism in which a foreign gene has been inserted. Such an organism could be a plant, an animal, bacteria or fungi. Foreign genes have also been injected into the embryo or the fertilised egg of an organism.

Importance of Genetic Engineering

◆ Successful alterations in the genetic makeup of an organism

◆ Valuable tool for increasing food production from plants and animals

◆ Diagnoses of diseases and improvements in medical treatment

(b) **Plant Tissue Culture:** It represents the method of growing tissues of plants in sterile conditions, in known artificial nutrient medium in laboratory conditions, for producing new plants.

(c) **Monoclonal Antibody (MAb):** The monoclonal antibodies are particular protein-type molecules formed in the laboratory. These are a kind of defence workers, which protect us from different types of diseases. Our body produces them naturally when invaded by any bacteria or virus. Many diagnostic tests for bacteria and viruses also use them, besides their application for fighting against cancer. Interferon is a specific protein synthesised from genetically engineered bacterial species *E. coli*. The human body produces them naturally to fight proteins for opposing viral infections. The biologically created interferon has been tested and found successful.

(d) **Synthesis of Enzymes:** The various enzymes synthesised via biotechnology are used in various processes such as stain removing, fabric softening, digestible food preparation, meat processing and cancer treatment.

(e) **Synthesis of Biodegradable Plastics/Bioplastics:** Biodegradable plastic, unlike other plastics, can be broken down into simpler substances by microorganisms.

(f) **Blood Substitute:** Biotechnologists are trying to synthesise artificial blood. This can bridge the gap between the need of blood for transfusion and available blood during accidents and disease outbreak. Biotechnologists like Mary L. Nucci and

Abraham Abuchowski (1998) are expected to be successful in this regard in their experiments.

(g) **Biotechnology and Mining:** Specific bacteria work on the particular metallic compounds found inside the earth. Hence, some bacteria are being currently employed in the extraction of different metals such as copper, zinc, lead and other metals. They also serve during the isolation of respective metals.

(h) **Cloning:** Cloning is application of biotechnology to produce cells or organisms being originally derived from a single organism or cell through asexual method in laboratory conditions. The organisms formed at the time of cloning have similar genes and are termed as clones. A clone is an individual cell or organism developed by a single cell of body and is genetically similar to its parental cell. In 1950s, scientists initiated the cloning of frogs and until the 1980s, mice were cloned. In the year 1996, Ian Wilmot was successful for the first time in the cloning of an adult sheep. He succeeded with his team of researchers and the clone was named as Dolly.

(i) **Food and Beverage:** A huge number of food products are manufactured industrially through application of fermentation technology. Some popular examples of those products include wine, yoghurt, cheese, bread, probiotic foods etc. Not only this, biotechnology also enabled production of different vitamins, amino acids and vinegar.

Probiotics

Probiotics are living microorganisms that are intended to have health benefits when consumed by the human body. They can be found in yogurt and other fermented foods and dietary supplements. Yogurt is a well-known food source of probiotics. Certain strains of bacteria in yogurt have ß-D-galactosidase, which is an enzyme that helps **break down lactose in dairy products into sugars (glucose and galactose).** Thus probiotics help in the digestion of milk sugars. The most common place linked to beneficial microbes is your gut (caecum).

Good bacteria keep humans healthy by supporting their immune function and controlling inflammation. There are various uses of probiotics:

- Helps body to digest food.
- Keeps bad bacteria from getting out of control and making a person sick.
- Synthesises the vitamins.
- Helps support the cells present in the line of your gut to prevent bad bacteria that you may have consumed (through food or drinks) from entering your blood.
- Breakdown and absorb medications.

There are two specific types of bacteria that are common probiotics found in stores. Probiotics are also made up of good yeast. These include:

- *Lactobacillus* (Bacteria)
- *Bifidobacterium* (Bacteria)
- *Saccharomyces boulardii* (Yeast)

(j) **Pharmaceuticals:** Important examples are as follows:

- Human insulin produced from non-human sources, production of interferon, cytokinin, steroids and human growth hormones.
- Gene-therapy to prevent and control diseases
- Vaccines and antibodies development.

(k) **Pollution Control:** The aerobic and anaerobic bacteria are being used for making manure from crop residues and animal wastes, in order to combat the problem of organic solid waste. The species of bacteria such as *Pseudomonas aeruginosa* is capable of eating away the oil spilled on the sea surface. Solid wastes such as crop residues can form biogas, being the most appropriate rural energy source. In environment, the atmospheric carbon dioxide is controlled by green plants during photosynthesis. Therefore, fast-growing species of trees developed through biotechnology will be an important tool to control the rising CO_2 level.

(l) **Waste Water Treatment:** The complex organic and nitrogenous waste can be degraded through biotechnology by employing bacteria, fungi, algae, etc. The process involves passing of the effluent through a microbial slime layer. The layer contains microbes, which help in the degradation of the organic and nitrogenous waste, releasing carbon dioxide and nitrogen dioxide.

(m) **Degradation of Pesticides:** Bacteria species such as Pseudomonas sp., Flavobacterium, Azotobacter, *E. coli,* etc., can degrade different pesticides. These microorganisms are genetically created for degrading a large number of pesticides.

(n) **Bioremediation:** Bioremediation is defined as the reclamation of environment through application of biotic agents like microorganism.

(o) **Industrial Applications:** Industrial processes like production of stain remover, detergents, bread, biotech-polyester, vitamins, stone-washed denims, bleached paper, etc., all deploy biotechnology. The enzyme cellulose is used for fading denims.

23.5 ACHIEVEMENTS OF BIOTECHNOLOGY IN DIFFERENT FIELDS

1. Biomedical

Diagnosis and therapy account for 68% of the biotechnology industry in the USA, 43.7% in Canada and about 43% in Europe. For example:

- Recombinant drugs, like human insulin, growth hormone, interferon, erythropoietin.
- Recombinant diagnostic kits (e.g., testing HIV, or pregnancy)
- Recombinant vaccines (e.g., against Hepatitis B and AIDS)
- Production of medicines by transgenic plants or animals (in milk or urine)

2. Agriculture

- Genetically modified crops that are resistant to pests, viruses, drought, etc.
- Genetically modified crops that ripen slowly during transport
- Use of organic material to produce biodegradable plastics, fuel, fertiliser
- In vitro fertilisation of farm animals using selected sperm and eggs
- Use of recombinant growth hormone to increase milk and meat production
- Genetically modified crops with better nutritional qualities

3. Marine Biotechnology

- Fish farming (aquaculture)
- Seaweed farming to produce fatty acids, etc.
- Production of adhesives from mussels and barnacles
- Use of enzymes from thermophile bacteria (usually living in dark, sulphurous, hot environments in the deep sea) for waste removal, or in sequencing DNA.

4. Environmental Biotechnology

- Fighting pollution using enzymes or microbes (e.g., oil spills)
- Use of plants to remove contamination by heavy metals
- Water treatment
- Treatment of air pollution

5. Forestry

- Production of tree clones from tissue culture
- Production of wood pulp for the paper industry

6. Other Applications

- Production of energy from biomass
- Biological sensors and switches for electronic processes
- Conservation of endangered species using cloning

23.6 TERMINOLOGY RELATED TO MODERN BIOTECHNOLOGY

- Blue biotechnology describes the applications of biotechnology in the field of marine and aquatic fields.
- Green biotechnology represents application of biotechnology in agricultural processes. Like selection and domestication of plants *via* micro propagation, designing and then growing transgenic plants under specific environments (cold, hot, dry, humid), in the presence (or absence) of chemicals. It might produce more eco-friendly solutions than the conventional industrial agriculture.
- Red biotechnology applies to medical processes. For example, the organisms designed for producing antibiotics, and genetic cures with the help of genetic manipulation.
- White biotechnology or industrial biotechnology is used in industrial processes, which includes designing of an organism for creating a useful chemical. The enzymes are used an industrial catalysts for manufacturing either valuable chemicals or destroying hazardous/polluting chemicals. Bioeconomy represents economical output and venturing all the applied biotechnologies types.

Biotechnology is defined in different colours on the basis of various applications:

Colour Type	Area of Biotech Activities
Red	Health, Medical, Diagnostics
Yellow	Food Biotechnology, Nutrition Science
Blue	Aquaculture, Coastal and Marine Biotech
Green	Agricultural, Environmental Biotechnology – Biofuels, Biofertilisers, Bioremediation, Geomicrobiology
Brown	Arid Zone and Desert Biotechnology
Dark	Bioterrorism, Biowarfare, Biocrimes, Anticrop warfare
Purple	Patents, Publications, Inventions, IPRs
White	Gene-based Bioindustries
Gold	Bioinformatics, Nanobiotechnology
Grey	Classical Fermentation and Bioprocess Technology

23.7 GENETIC ENGINEERING

Genetic engineering is a technique of manipulating the organism's genome with the help of biotechnology to add one or more traits that are not found in the organism naturally. The technique is also called gene manipulation/genetic modification. This process takes a number of steps: the first of which is the constitution of DNA segment from nucleic acid molecules in a test tube. The DNA so made is inserted into a vector (vector could be virus or some other suitable organism) that can serve as a molecular ferry to carry it into the host organism. The inserted DNA molecule expresses itself and also multiplies. Genetic engineering enhances the plant and animal food production, diagnosis of disease, improvement of medical treatment, and produces vaccines and other useful drugs. Additionally, it helps in the disposal of industrial wastes and the plants and animals' selective breeding, hybridisation and recombinant DNA. Various techniques are involved in genetic engineering, like isolation of genes, synthesis of genes, recombinant DNA and gene cloning, etc.

Hazards of Genetic Engineering

1. If a wrong DNA segment is inserted and if it gets expressed, it can cause new diseases in human beings.
2. It can be used in biological warfare.
3. Genetic modification of existing species/recreation of extinct species can lead to disasters.
4. Scientists are prone to making mistakes – new strains of bacteria, fauna, etc., can come out of labs, which could be hostile to human beings.
5. Even in a single species, genetic engineering could lead to elimination of varieties; if some new disease comes up, the entire species may be wiped out.

PART – (B) GENE, GENOME AND BIOTECHNOLOGICAL TOOLS

23.8 GENE

Gene is hereditary unit of living organism. It is a small segment of DNA (deoxyribonucleic acid) or RNA (ribonucleic acid) located on chromosome, which codes for a protein with specific function in the organism. This information passes through genetic traits to the off-spring. An allele is an alternate form of gene, present on homologous chromosome. The gene (specific base pair sequence of DNA) undergoes transcription, a process to produce messenger RNA. This mRNA, through translation process, synthesises proteins. Transcription and translation together constitute central dogma. So the gene is processed ultimately to produce protein.

23.8.1 National Gene Bank (NGB)

It was established in 1996 to preserve the seeds of Plant Genetic Resources (PGR) for future generations. It has the capacity to preserve about one million germplasm in the form of seeds. It stores different crop groups such as cereals, millets, medicinal and aromatic plants, and narcotics, etc. In 2021, the National Gene Bank (NGB) was protecting 4.52 lakh accessions, of which 2.7 lakh were Indian germplasm while the rest were imported from other countries.

NGB has four kinds of facilities to cater to long-term as well as medium-term conservation namely:

1. Seed Gene bank (–18°C).
2. Cryo gene bank (–170°C to –196°C).
3. In-vitro Gene bank (25°C).
4. Field Gene bank.

Need for Gene Bank

It will make the farmers of the country self-reliant and the government has been making every effort in this direction.

Note: The world's second-largest refurbished state-of-the-art National Gene Bank was inaugurated in 2021 at the National Bureau of Plant Genetic Resources (NBPGR), Pusa, New Delhi.

Significance

1. Researchers or farmers can withdraw samples from these "gene" banks to help rebuild populations of rare plant varieties and animal breeds or to help increase genetic diversity within species.
2. Gene banks also preserve cells or organisms that host unusual gene variants – genes with special traits. Those genes might later prove useful if some epidemic strikes, in case of climate changes or when other factors threaten the survival of plants or animals.
3. Farmers could use the banked deposits, stored cells or tissues to restore genetic diversity or to introduce traits from other breeds or varieties.

23.9 DNA STRUCTURE AND ITS COMPOSITION

The genes are encoded in long strands of DNA for majority of living beings. DNA consists of a double helical chain made of four types of nucleotide subunits [adenine (A), guanine (G), cytosine (C), and thymine (T)], sugar (deoxyribose), and a phosphate group.

Nucleotide = Nucleoside + Phosphoric acid

Nucleoside = Nitrogenous base + Sugar

Nitrogenous Base: Purine (Adenine, Guanine), Pyrimidine (Cytosine, Thymine and Uracil)

23.9.1 DNA Fingerprinting or Genomic Fingerprinting

DNA fingerprint is a characteristic feature of every individual. It is a technology which is adopted by the forensic scientists to identify the individuals by their respective DNA profiles. It is also called as DNA profiling, DNA testing, DNA typing, or genetic fingerprinting or gene mapping or genography. It serves an important role as legal evidence in court to prosecute or defend alleged criminals. The chemical structure of the DNA of every individual is same but the difference is in the base pairs' ordering. The information enclosed in DNA is calculated mainly by the letters sequence along the zipper.

The encrypted sets of numbers showing a person's DNA makeup are called DNA profiles. It can also be used in the identification of individuals and in parental testing and investigation of criminals. In paternity cases, DNA fingerprinting technology can be used to determine persons as biological parents of a child. Although 99.9 per cent of human DNA sequences are similar in every person, only 0.1 per cent of human DNA is unique. Sir Alec Jeffreys at the University of Leicester in England first reported DNA profiling technique in 1984. The DNA fingerprinting advancement is undertaken for quicker and precise identification of criminal suspects during investigations. The DNA fingerprints of all tried and convicted criminals are stored in a database for identification.

23.9.1.1 DNA Fingerprinting is Performed in the following Research Institutes in India

1. Centre for Cellular and Molecular Biology (CCMB), Hyderabad
2. Centre for DNA Fingerprinting (CDFD), Hyderabad
3. National Bureau of Plant Genetic Resource (NBPGR), New Delhi
4. National Institute of Plant and Genetic Research (NIPGR), New Delhi

23.9.1.2 Process of DNA Fingerprinting

It includes the following steps:

1. DNA isolation.
2. **Cutting, sizing and sorting:** Specific enzymes known as restriction enzymes are used for cutting of the DNA at specific places.
3. **Transfer of DNA to nylon:** The DNA pieces distribution is moved to a nylon sheet by keeping the sheet on the gel and soaking them overnight.
4. **Probing:** When radioactive or coloured probes are attached to the nylon sheet, a pattern is produced termed as the DNA fingerprint.
5. **DNA Fingerprint:** The final DNA fingerprint is produced by the usage of several probes (510 or more) at the same time.
6. Blotting techniques used in different segment measurements include:
   - Southern Blotting – DNA
   - Northern Blotting – RNA
   - Western Blotting – Protein

23.9.1.3 Applications of DNA Fingerprinting

1. **Paternity and Maternity:** Analysis of VNTR (Virtual Number Tandem Repeat) pattern of parent–child has been used to solve the father-identification cases.
2. **In Forensic Sciences:** DNA isolated from blood, hair, skin cells or other genetic evidence left at the scene of a crime can be used to identify criminals. Police from all over the world are using this technique to link the suspects with their biological evidence.
3. **Personal Identification:** DNA fingerprints can be used as a genetic bar code to identify individuals.
4. **Diagnosis of Inherited Disorders:** It can help to diagnose inherited disorders in both prenatal and newborn babies. Disorders included under these are cystic fibrosis, haemophilia, Huntington's disease, familial Alzheimer's, sickle cell anaemia, thalassaemia and many others.

23.9.2 Junk DNA

Susumu Ohno introduced the term 'Junk DNA' in 1972 as a provisional label for the portions of a genome sequence, which have no discernible function.

There are several evidences indicating that 'junk DNA' sequences are likely to have unidentified functional activity. Though current researches indicates that this DNA is not 'junk' at all, in fact it has been formulated that it has various regulatory roles. It implies that this so-called 'non-coding DNA' influences the behaviour of the genes of the 'coding DNA', in important ways. However, we know very little about this DNA and especially regarding non-coding DNA and the DNA of genes.

23.9.3 DNA Barcoding

A technique for specifying the organisms' species with the usage of a short sequence of DNA situated in the genome is termed as DNA barcoding. Its primary objective is to identify an unknown sample in terms of a known classification rather than determine classification. And hence, it differs significantly from molecular phylogeny. The barcode DNA sequences are too short in respect of the complete genome and hence reasonably available and are cheaper too. The cytochrome c oxidase subunit 1 mitochondrial region (COI) is emerging as the standard barcode region for higher animals. It is 648-nucleotide base-pairs long in most groups, a very short sequence as compared to 3 billion base-pairs in the human genome. Applications of DNA barcoding are given below:

1. Identification of plant leaves even in absence of flowers or fruit,
2. Identification of insect larvae (with typically fewer diagnostic characters than adults),
3. Identification of the diet of an animal based on stomach contents or faeces, and
4. Identification of products in commerce (e.g., herbal supplements or wood).

DNA barcodes allow non-experts to objectively identify species even from small, damaged, or industrially processed material. Just as the unique pattern of bars in a universal product code (UPC) identifies each consumer product, a "DNA barcode" is a unique pattern of DNA sequence that can potentially identify each living thing.

Chloroplast DNA and Mitochondrial DNA barcoding protocols are being used more and more in the food industry and food supply chains for food labelling, not only to support food safety but also to uncover food piracy in freshly commercialised and technologically processed products. DNA barcoding helps to identify undesirable animal or plant materials in processed foods.

Many scientists criticise DNA barcoding due to various reasons:

1. Lack of reliable information above the species level from DNA barcoding.
2. Some resent what they see as a gross oversimplification of the science of taxonomy.
3. As per others, recently diverged species might not be distinguishable based on their COI sequences.

23.9.4 Environmental DNA (e-DNA)

Aerial Metagenomics is the part of environmental DNA (e-DNA). Recent studies found that DNA floating in the air can boost biodiversity conservation efforts across the world. It is also shown that e-DNA can potentially identify and monitor terrestrial animals.

Animals shed DNA through their breath, saliva, fur or faeces into the environment. These samples are called e-DNA.

Significance

- e-DNA could help understand the composition of animal communities and detect the spread of non-native species.
- In its current form, this method cannot provide accurate data for population census but will soon overcome this limitation in the future.
- The results of study indicate a big potential for airborne e-DNA to be used for conservation of terrestrial vertebrates.
- This method will work with the current techniques to monitor endangered species after some fine-tuning.
- This method allows for biomonitoring without requiring the collection of the living organism.
- It allows creating the ability to study organisms that are invasive, elusive or endangered without introducing anthropogenic stress on the organism.
- Access to this genetic information makes a critical contribution to the understanding of population size, species distribution and population dynamics for species not well documented.
- Importantly, e-DNA is often more cost-effective compared to traditional sampling methods.

23.9.4 Genetic Marker

A short sequence of DNA or microsatellites with a recognised position on a chromosome, useful in identifying cells, individuals or species is known as a genetic marker. A mutation or alteration in the genomic loci may cause this variation. It may be a **small DNA sequence**, such as a sequence around a single base-pair change termed as single nucleotide polymorphism, or a long sequence such as minisatellites. From many years, in most organisms, the gene mapping was restricted. The usage of genetic makers can be undertaken for studying the connection between an inherited disease and its genetic cause.

Microsatellites are one of the best suitable genetic markers for analysing pedigree, population structure, genome variation, evolutionary process or demographic history, and fingerprinting purposes. Genetic markers are basically of two types – Protein and DNA (molecular).

GREEN FLUORESCENT PROTEIN

A gene from a jellyfish (*Aequorea victoria*), which encodes a fluorescent protein called Green fluorescent protein (GFP), may be linked physically and thus together expressed with the genes of mammals. This enables the identification of the location of the protein encoded by the GFP-tagged gene in the mammalian cell. It is a bioluminescent protein. GFP can be included into a range of biological systems for the purpose of functioning as a marker protein. GFP has significantly contributed to multiple research fields like monitoring gene expression, localisation, mobility, traffic, interactions between various membrane and cytoplasmic proteins, etc.

23.10 GENOME

A genome is an entire set of DNA of an organism, which contains hereditary information. It consists of both the DNA or RNA genes and the non-coding sequences. Prokaryotes usually store their genomes on a single chromosome and eukaryotes store their genome on one or more chromosomes. As we know that DNA is present in nucleus as well as some organelle (mitochondria, chloroplast) and based on this, the genome term can be applied specifically for specifically storing a complete nuclear DNA set but can also be applied for storing within organelles. The 'genome' of any given individual (except for identical twins and cloned organisms) is unique. Genome that can chemically be synthesised in lab is known as artificial or synthetic genome.

23.10.1 Genome or DNA or Nucleotide Sequencing

Genome sequencing is a laboratory process through which scientists get the complete DNA sequence (in terms of A, T, G, C) of an organism's genome at a time. DNA-containing cells such as saliva, epithelial cells, bone marrow, hair (as long as the hair contains a hair follicle), seeds, plant leaves, are used as samples for sequencing. Genome sequencing is done by an instrument called as automated DNA sequencers.

23.10.2 Specific Applications of Genome Research

Some current and potential applications of genome research include:

1. Medicine
2. Evolutionary biology and anthropology
3. Energy and environmental applications
4. DNA forensics
5. Agriculture

1. Medicine

- Improved diagnosis of disease and earlier detection of genetic predispositions to disease
- Rational drug design
- Gene therapy
- Assess health damage and risks due to exposure of radiation, exposure to mutagenic chemicals and cancer-causing toxins
- Reduce the possibility of heritable mutations

2. Evolutionary Biology and Anthropology

- Study of evolution
- Study of migration of different human population groups

3. Energy and Environmental Applications

- Creating new sources of energy (bio-fuels)
- Use microbial genomics for creating environmental monitoring techniques for the detection of pollutants, safe and efficient environmental remediation, and carbon sequestration
- Detect bacteria and other organisms that may pollute air, water, soil and food

4. DNA Forensics

- Identification of possible suspects whose DNA may match proof remained at crime scenes
- Acquitting those persons who are falsely accused in crimes
- Identification of victims of crime and catastrophe during transplantation, matching organ donors with recipients

5. Agriculture

- Development of productive, and disease, insect and drought-resistant crops (GM crops)
- Developing healthier, more productive, disease-resistant farm animals (Transgenic)
- Foods with higher nutritional content (GM foods)

23.10.3 Human Genome Project (HGP)/ Human Genome Sequencing

The Human Genome Project (HGP) was a 13-year effort, which formally began in 1990 and completed in 2003 as a global project of scientific research. The main goal was to determine the sequence of the genes present in human DNA.

23.10.3.1 Project Goals

1. Identification of approximately 24,000 human DNA genes
2. Determining the 3 billion chemical base pairs (300 Mega base pairs/3 × 10^9 base pair) sequences consisting of human DNA
3. Information storage in databases
4. Improving tools for analysis of data
5. Transfer-related technologies to the private sector
6. Addressing of the ethical, legal and social issues (ELSI) arising from the project

The participating countries were the US, the UK, France, Germany, Japan and China.

The human DNA sequence is piled up in databases, which are freely available on the Internet. **'GenBank'** is the databank of The US National Center for Biotechnology Information and its sister organisations based at Europe and Japan, which contains sequence of genes along with recognised and imaginary genes and proteins sequences. For the data analysis, various computer programmes are created since it is difficult for the data interpretation itself without such programmes.

23.10.3.2 Human Genome Project – Read and Write (HGP-Read and HGP-Write)

1. HGP-Read

- This was an international and multi-institutional effort that took 13 years [1990–2003] and $2.7 billion to produce a blueprint of the human genome.
- The HGP has revealed that there are probably about 20,500 human genes composed of over 3 billion base pairs.
- India did not participate in HGP-read.

2. ***HGP-Write***

- This project was launched in 2016 to write or build an artificial human genome from scratch with sophisticated bioengineering tools.
- It aims to address a large number of human health problems of which some of the potential challenges are rising human organs transplantation, devising viruses immunity in cell lines through genome-wide recoding, devising cancer resistance into new therapeutic cell lines, and increasing high-productivity, cost-efficient and pharmaceutical development through the usage of human cells and organoids.
- The encouragement of project property through the accessing of broad intellectual property by the use of patent pooling.
- But, the HGP-write will require public involvement and consideration of ethical, legal and social implications.

23.10.3.3 HGP and its Benefits

The goal of sequencing and identifying all three billion chemical units in the human genetic instruction set and determining the genetic roots of disease for further development of treatments lead to Human Genome Project. In April 2003, the sequencing of the human genome was successfully completed by Human Genome Project, which sequenced about 99 per cent of the human genome's gene-containing regions with an accuracy of 99.99 per cent of the 3 billion DNA letters in the human genome.

1. Post sequencing, the next step is identification of the genetic variants which are involved in increasing the risk for common diseases like cancer and diabetes. The interpretation of genome data, as a task, is still in its initial stages. It is expected that detailed knowledge of the human genome will serve with new avenues for advances in medicine and biotechnology.
2. New therapeutic procedures may be determined by deeper understanding of disease processing at molecular biology level. There is establishment of DNA significance in molecular biology and understanding its central role in calculating the basic cellular processes operation, which will facilitate medical advances in various fields of clinical interest.
3. The data from this project is expected to answer several questions involving similarities and differences between humans and our closest relatives (the primates and the other mammals).
4. They offer numerous benefits for biological scientists, as in, a researcher investigating a certain form of cancer can narrow down his/ her search to a particular gene. By visiting the human genome database on the World Wide Web, more data about this particular gene and its properties can be used.
5. Identification of predictive and predisposition markers would be accelerated by harnessing the huge amount of genetic variability available for common and complex diseases genes as well as individual responsiveness to medications and different environments.

23.10.3.4 Missing in Genome Sequencing

- The genetic sequence made available in 2003 from the **Human Genome Project**, which is an international collaboration between that happened between 1990 and 2003, contained information from a region of the human genome known as the **euchromatin.** Here, the chromosome is rich in genes, and the DNA encodes for protein.
- **The 8% chromosome that** was left out was in the area called **heterochromatin**. This is a smaller portion of the genome, and does not produce protein.
- There were at least two key reasons why heterochromatin was given lower priority. This part of the genome was thought to be "**junk DNA**", because it had no clear function. Besides, the euchromatin contained more genes that were simpler to sequence with the tools available at the time.
- Now, the fully sequenced genome is the result of the efforts of a global collaboration called the **Telomere-2-Telomere (T2T) project.** The invention of new methods of DNA sequencing and computational analysis helped complete the reading of the remaining 8% of the genome.
- **Genome sequencing** is the process that involves deciphering the exact order of base pairs in an individual. This 'deciphering' or reading of the genome is what sequencing is all about. Cost of

sequencing differ based on the methods employed to do the reading or the accuracy stressed upon in decoding the genome.

23.10.3.5 Need for Genome Sequencing

- Ever since the human genome was first sequenced in 2003, it opened a fresh perspective on the *link between disease and the unique genetic make-up of each individual.*
- Nearly 10,000 diseases – including cystic fibrosis, thalassemia – are known to be the result of a single gene malfunctioning.
- While genes may render some insensitive to certain drugs, genome sequencing has shown that cancer too can be understood from the viewpoint of genetics, rather than being seen as a disease of certain organs.

23.10.3.6 Importance of Genome Sequencing

- A genetic test, which is commercially available at several outlets in the country, usually involves analysing only a portion of the genome that is known to contain aberrant genes linked to disease.
- It is important to ensure that India, with its unparalleled human diversity, is adequately represented in terms of genomic data and develops indigenous capacity to generate, maintain, analyse, utilise and communicate large-scale genome data, in a scalable manner.
- The human genome has about 3.2 billion base pairs and just 10 years ago cost about $10,000. Now prices have fallen to a tenth.

(Refer **Infographic – Human Genome Project**)

23.10.3.7 Indian Human Genome Project / India's Efforts towards Genome Sequencing

CSIR scientists at the Institute of Genomics and Integrative Biology (IGIB), Delhi, have sequenced the anonymous healthy Indian citizen Human Genome.

Due to lack of resources, India could not be a part of the Human Genome Project in the early nineties. After the first human genome sequence completion in India, the country is presently party to the league of few countries, such as United States, China, Canada, United Kingdom and South Korea who have shown their capability of sequencing and assembling complete human genomes.

The first Human Genome Sequence effort took more than a decade and huge capital i,e. around billion US dollars, CSIR scientists at IGIB accomplished complete sequencing and assembly in a comparatively much shorter time. Within 10 weeks, from September 25 to December 4, 2009, the feat was achieved by the IGIB scientists. CSIR was able to achieve this feat through the adoption of latest technologies and through successfully combining its high estimating abilities.

It opened newer vistas for low cost affordable healthcare and predictive medicine in future for the masses. Consequently, understanding several diseases important to India and other developing countries would get improved, adding to the global knowledge on genetic variations and predisposition to various diseases. The genetic diversity of the Indian population had been successfully completed by CSIR along with the genome sequence of a fish variety, called Zebra fish, popularly used by the scientific community as an organism for modelling human diseases.

INDIGEN GENOME PROJECT

- The IndiGen initiative was undertaken by CSIR in April 2019, which was implemented by the CSIR-Institute of Genomics and Integrative Biology (IGIB), Delhi and CSIR-Centre for Cellular and Molecular Biology (CCMB), Hyderabad.
- The objective is to enable genetic epidemiology and develop public health technologies applications using population genome data.
- This has enabled benchmarking the scalability of genome sequencing and computational analysis at population scale in a defined timeline.
- The ability to decode the genetic blueprint of humans through whole genome sequencing will be a major driver for biomedical science.

IndiGen programme aims to undertake whole genome sequencing of thousands of individuals representing diverse ethnic groups from India.

Indian Genome Variation Initiative

The Indian Genome Variation initiative is a network programme initiated in 2003 for 5 years, with the help of six constituent laboratories of the Council of Scientific and Industrial Research (CSIR), with funding from Indian Government. It aims to provide data on the sub-population's variations, which will be useful for

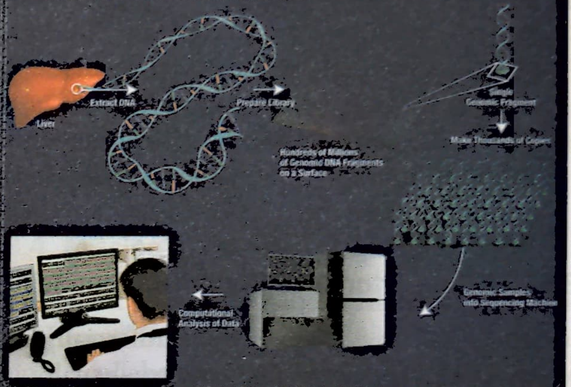
THE HUMAN GENOME PROJECT

WHAT IS HUMAN GENOME PROJECT?

- The Human Genome Project (HGP) was an international scientific research initiative aimed at mapping and sequencing the entire human genome. It was one of the most significant scientific undertakings of the 20th century and had a profound impact on our understanding of genetics, human biology, and disease.
- The project was officially launched in 1990 as a collaborative effort between several countries, including the United States, the United Kingdom, France, Germany, Japan, and China. The primary goal of the HGP was to determine the sequence of chemical base pairs that make up human DNA and identify and map approximately 20,000-25,000 genes present in the human genome.
- The project gave the understanding that the human genome has numerous implications for fields such as medicine, genetics, and biotechnology. By deciphering the sequence of DNA, scientists aimed to gain insights into the genetic basis of diseases, identify potential therapeutic targets, and develop personalized medicine approaches.
- The HGP utilized a combination of experimental techniques and computational methods to sequence the DNA. It involved the development of new technologies and approaches to efficiently and accurately read the genetic code. Initially, the project was estimated to take 15 years to complete, but with advancements in sequencing technology and collaborative efforts, it was completed ahead of schedule in 2003.
- The successful completion of the Human Genome Project marked a significant milestone in genomics research. It provided researchers with a comprehensive reference for the human genome, which has since become an invaluable resource for studying genetic variation, understanding human evolution, and investigating the genetic basis of diseases.
- Since the completion of the HGP, the field of genomics has rapidly advanced, with the development of next-generation sequencing technologies that have made genome sequencing faster, more accessible, and less expensive. These advancements have facilitated large-scale genomic studies, leading to breakthroughs in personalized medicine, genetic diagnostics, and our understanding of complex genetic disorders.
- In summary, the Human Genome Project was an international collaborative effort to map and sequence the entire human genome. Its successful completion has revolutionized the field of genomics and paved the way for significant advancements in medicine, genetics, and biotechnology.

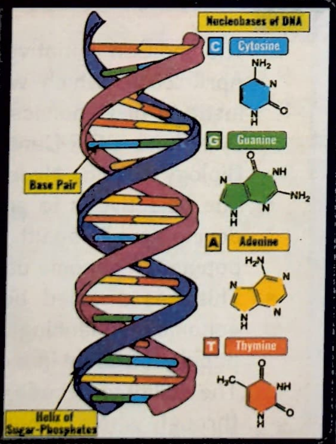
WHAT IS DNA SEQUENCING?

- DNA sequencing determines base order using labeled nucleotides.
- Sequencing by synthesis generates new DNA using polymerase.
- Incorporating labeled nucleotides emits fluorescent signals.
- Each signal corresponds to a specific nucleotide.
- Reads of 125 nucleotides can be generated in large quantities.
- Overlapping reads are assembled for accuracy.
- Sequencing identifies genetic variations and mutations.
- Variations can be single base changes or large deletions.
- Sequencing helps study disease development and progression.
- It uncovers disease-causing changes.


Liver
Extract DNA
Prepare Library
Hundreds of Millions of Genomic DNA Fragments on a Surface
Single Genomic Fragment
Make Thousands of Copies
Genomic Samples into Sequencing Machine
Computational Analysis of Data

WHAT IS DNA?

- Deoxyribonucleic acid (DNA) is the chemical compound that contains the instructions needed to develop and direct the activities of nearly all living organisms. DNA molecules are made of two twisting, paired strands, often referred to as a double helix.
- Each DNA strand is made of four chemical units, called nucleotide bases, which comprise the genetic "alphabet." The bases are adenine (A), thymine (T), guanine (G), and cytosine (C). Bases on opposite strands pair specifically: an A always pairs with a T; a C always pairs with a G. The order of the As, Ts, Cs and Gs determines the meaning of the information encoded in that part of the DNA molecule just as the order of letters determines the meaning of a word.



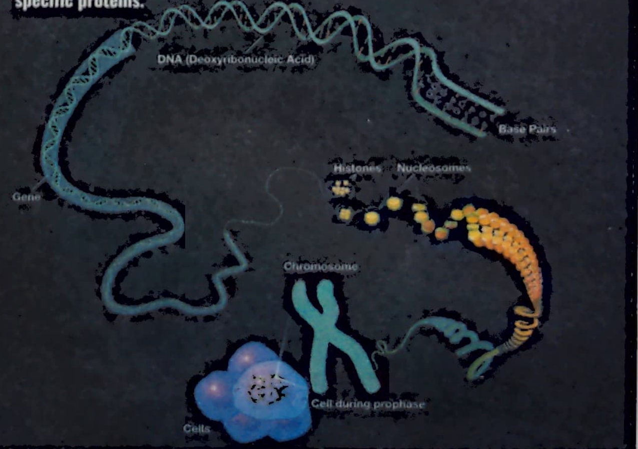
COLLABORATIVE EFFORT

KEY FACTS

1. Total DNA base pairs: Approximately 3 billion.
2. Human genome: Organized into 23 pairs of chromosomes.
3. Number of genes: About 20,000-25,000 in the human genome.
4. Project Duration: 1990-2003 (13 years).
5. DNA sequencing machines: Crucial for generating sequence data.
6. Sequencing multiple individuals: Accounting for genetic variations.
7. Comparative genomics: Comparing the human genome with other species.
8. Disease-related gene discoveries: Identification of genes associated with diseases.
9. Personalized medicine: Foundation for tailoring treatments based on genetics.
10. Ethical, legal, and social implications (ELSI): Addressed through research and guidelines.

WHAT IS GENOME?

- The genome refers to an organism's complete set of DNA, which contains approximately 3 billion base pairs in the case of the human genome. DNA carries the instructions required to build and maintain an entire organism.
- Genes are specific units of DNA that carry instructions for producing proteins. The human genome is estimated to have between 20,000 and 25,000 genes, with each gene coding for an average of three proteins.
- Proteins play vital roles in the body, including forming structures such as organs and tissues, controlling chemical reactions, and transmitting signals between cells. When DNA is mutated, it can lead to the production of abnormal proteins, disrupting normal bodily processes and potentially causing diseases like cancer. Genes are located on 23 pairs of chromosomes within the nucleus of human cells. They direct the production of proteins through a process involving enzymes and messenger molecules. An enzyme copies the information from a gene's DNA into messenger RNA (mRNA). The mRNA then travels from the nucleus to the cell's cytoplasm, where it is read by ribosomes. Ribosomes use the information to link amino acids together in the correct sequence, forming specific proteins.



SIGNIFICANCE AND ACHIEVEMENTS

Identification of Disease-Related Genes: The Human Genome Project contributed to the discovery of numerous genes associated with diseases. By mapping and sequencing the human genome, researchers identified genetic variations linked to various conditions, including cancer, heart disease, and genetic disorders. This knowledge has led to improved diagnostics, targeted therapies, and a better understanding of disease mechanisms.

Comparative Genomics: Comparing the human genome with the genomes of other species provided valuable insights into evolutionary relationships and genetic similarities. The Human Genome Project helped identify conserved regions across species, highlighting the importance of certain genes and genetic elements in biological processes.

Personalized Medicine: The project laid the foundation for personalized medicine, an approach that considers an individual's genetic makeup in healthcare. By understanding the genetic variations among individuals, healthcare professionals can tailor treatments and medications to specific genetic profiles, improving their effectiveness and reducing adverse reactions.

Ethical, Legal, and Social Implications (ELSI) Research: The Human Genome Project incorporated research on the ethical, legal, and social aspects of genomics. This research helped identify and address the ethical challenges and societal implications of genomic advancements, such as privacy concerns, genetic discrimination, and access to genetic information. It led to the establishment of guidelines, policies, and legislation to protect individuals and promote responsible use of genomic data.

Advancements in Genomic Research: The Human Genome Project paved the way for significant advancements in genomic research. It provided a vast amount of data and tools that have fueled subsequent research endeavors. This knowledge has accelerated breakthroughs in various fields, including cancer research, genetic therapies, pharmacogenomics, and understanding human evolution.

Publicly Available Genome Data: The Human Genome Project was committed to the principle of data sharing. As a result, the project made the human genome sequence data freely available to the scientific community and the public. This open access approach has democratized genomics research and has been instrumental in facilitating further discoveries and applications.

HUMAN GENOME PROJECT READ & WRITE

HGP Read

- This was an international and multi-institutional effort that took 13 years [1990–2003] and $ 2.7 billion to produce a blueprint of the human genome.
- The HGP has revealed that there are probably about 20,500 human genes composed of over 3 billion base pairs.
- India did not participate in HGP-read.

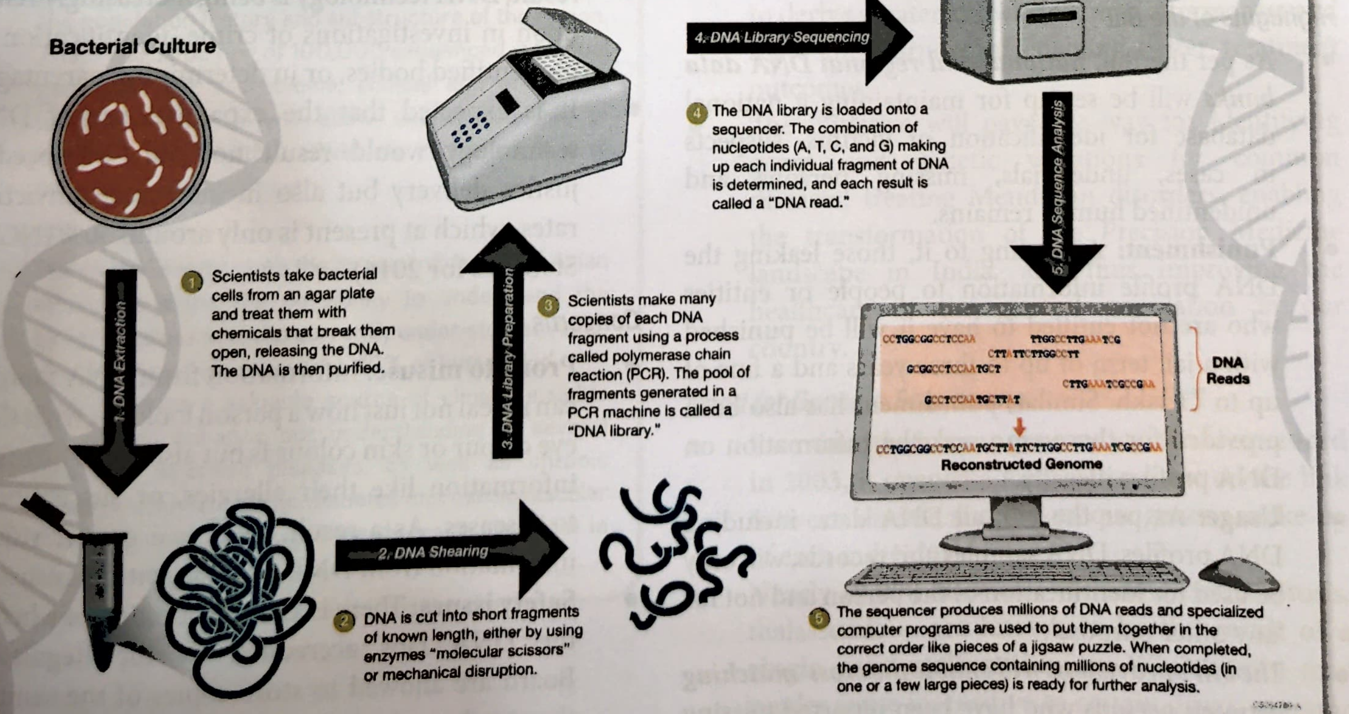
HGP Write

- This project was launched in 2016 to write or build an artificial human genome from scratch with sophisticated bioengineering tools.
- It aims to address a large number of human health problems of which some of the potential challenges are rising human organs transplantation, devising viruses immunity in cell lines through genome-wide recoding, devising cancer resistance into new therapeutic cell lines, and increasing high-productivity, cost-efficient and pharmaceutical development through the usage of human cells and organoids.
- It encouraged the project property through the accessing of broad intellectual property by the use of patent pooling.
- But, the HGP-write will require public involvement and consideration of ethical legal and social implications.

THE GENOME SEQUENCING PROCESS

The Whole Genome Sequencing (WGS) Process

WGS is a laboratory procedure that determines the order of bases in the genome of an organism in one process. WGS provides a very precise DNA fingerprint that can help link cases to one another allowing an outbreak to be detected and solved sooner.



① Scientists take bacterial cells from an agar plate and treat them with chemicals that break them open, releasing the DNA. The DNA is then purified.

② DNA is cut into short fragments of known length, either by using enzymes "molecular scissors" or mechanical disruption.

③ Scientists make many copies of each DNA fragment using a process called polymerase chain reaction (PCR). The pool of fragments generated in a PCR machine is called a "DNA library."

④ The DNA library is loaded onto a sequencer. The combination of nucleotides (A, T, C, and G) making up each individual fragment of DNA is determined, and each result is called a "DNA read."

⑤ The sequencer produces millions of DNA reads and specialized computer programs are used to put them together in the correct order like pieces of a jigsaw puzzle. When completed, the genome sequence containing millions of nucleotides (in one or a few large pieces) is ready for further analysis.

investigators in order to carry out the study of specific candidate gene in any part of the country. This is the first large-scale comprehensive study of the structure of the Indian population with wide-reaching implications.

Indian Genome Variation Database (IGVdb)

Being a consortium activity, the Indian Genome Variation database (IGVdb) is a part of the Indian Genome Variation initiative, established in 2003. It helps in understanding the intrinsic genetic variability of human sub-population being the first step in identifying vulnerable biomarkers for any disease.

20.10.4 DNA Technology Bill

The ***DNA Technology (Use and Application) Regulation Bill, 2019,*** which seeks to control the use of DNA technology for establishing the identity of a person, has been referred to a parliamentary standing committee for examination.

Need for the Legislation and its Significance

The utility of DNA-based technologies for solving crimes, and to identify missing persons, is well recognised across the world. Therefore, the new bill ***aims to expand the application of DNA-based forensic technologies to support and strengthen the justice delivery system of the country.***

Highlights of the Bill

- As per the Bill, ***national and regional DNA data banks*** will be set up for maintaining a national database for identification of victims, suspects in cases, undertrials, missing persons and unidentified human remains.
- **Punishment:** According to it, those leaking the DNA profile information to people or entities who are not entitled to have it will be punished with a jail term of up to three years and a fine of up to ₹1 lakh. Similar, punishment has also been provided for those who seek the information on DNA profiles illegally.
- **Usage:** As per the bill, all DNA data, including DNA profiles, DNA samples and records, will only be used for identification of the person and not for 'any other purpose'.
- ***The bill's provisions will enable the cross-matching between persons*** who have been reported missing on the one hand and unidentified dead bodies found in various parts of the country on the other, and also for establishing the identity of victims in mass disasters.
- The Bill establishes a ***DNA Regulatory Board*** to accredit the DNA laboratories that analyse DNA samples to establish the identity of an individual.

Benefits of the Bill

- By providing for the mandatory accreditation and regulation of DNA laboratories, the Bill seeks to ensure the proposed expanded use of this technology in the country.
- Assurance that the DNA test results are reliable and the data will remain protected from misuse or abuse in terms of the privacy rights of our citizens.

DNA Technology-Significance

- DNA analysis is an extremely useful and accurate technology in ascertaining the identity of a person from his/her DNA sample, or establishing biological relationships between individuals.
- A hair sample, or even bloodstains from clothes, from a scene of crime, for example, can be matched with that of a suspect, and it can, in most cases, be conclusively established whether the DNA in the sample belongs to the suspected individual. As a result, DNA technology is being increasingly relied upon in investigations of crime, identification of unidentified bodies, or in determining parentage.
- It is expected that the expanded use of DNA technology would result not only in speedier justice delivery but also in increased conviction rates, which at present is only around 30% (NCRB Statistics for 2016).

Concerns

- **Prone to misuse:** Information from DNA samples can reveal not just how a person looks, or what their eye colour or skin colour is but also more intrusive information like their allergies, or susceptibility to diseases. As a result, there is a greater risk of information from DNA analysis getting misused.
- **Safety issues:** There is also the question of whether the DNA labs accredited by the Regulatory Board are allowed to store copies of the samples they analyse. And if so, how the owners of those

samples can ensure the data is safe or needs to be removed from their own indices.

- **Issues over storage:** It is not clear if DNA samples collected to resolve civil disputes will also be stored in the databank (regional or national), although there is no index specific for the same. If they will be stored, then the problem cascades because the Bill also does not provide for information, consent and appeals.

100K GENOMEASIA PROJECT

100K GenomeAsia Project is a project with the presence of Indian Scientists and Companies which is being done at **Nanyang Technological University (NTU), Singapore, to sequence the whole genomes of 100K Asians, including 50,000 Indians.**

About 100K GenomeAsia Project

- A non-profit consortium project which has an ambitious plan to sequence 100,000 Asian individuals in hopes of fast-tracking precision medicine applications for Asian populations is termed as GenomeAsia 100K.
- Having influence on big data analytics and advances in data science and artificial intelligence. The participants will be selected from 12 South Asian countries and at least 7 North and East Asian countries.
- The first step of the project will be on creating phased reference genomes for all major Asian ethnic groups – representing a major step forward in understanding the population history and substructure of the region. There will be pairing of 100,000 sequenced individual genomes with microbiome, clinical and phenotype information which will allow deeper analysis of diseased and healthy individuals in the context of inferred local ancestries.

Significance

- The recent insights into the genome diversity of Asian ethnicities show the possibility to understand the biology of disease in the currently under-studied Asian populations which represent 40% of humankind.
- Also, provides a valuable source of clinical insights that should enhance our understanding of several rare and inherited diseases, as well as chronic diseases such as cancer, diabetes and cardiovascular disease by the unique genetic diversity prevalent in South, North and East Asia.

23.10.5 Genome India Initiative

The Department of Biotechnology (DBT) plans to scan nearly 20,000 Indian genomes over the next five years, in a two-phase exercise, and develop diagnostic tests that can be used to test for cancer.

Key Facts

- The first phase involves sequencing the complete genomes of nearly 10,000 Indians from all corners of the country and capture the biological diversity of India.
- In the next phase, about 10,000 'diseased individuals' would have their genomes sequenced. These vast troves of data sets would be compared using machine learning techniques to identify genes that can predict cancer risk, as well as other diseases that could be significantly influenced by genetic anomalies.

Significance

- The data generated would be accessible to researchers anywhere for analysis. This would be through a proposed National Biological Data Centre envisaged in a policy called the '**Biological Data Storage, Access and Sharing Policy**', which is still in early stages of discussion.
- As the genetic landscape differs across the world, it is necessary that genetic data is shared in order to derive greater knowledge from information and serve the purpose of enabling better treatment outcomes.
- The initiative will pave the way for identifying genes and genetic variations for common diseases, treating Mendelian disorders, enabling the transformation of the Precision Medicine landscape in India, and thus improving the healthcare of the general population in our country.

Need for Genome Sequencing

- Ever since **the human genome was first sequenced in 2003,** it opened a fresh perspective on the link between disease and the unique genetic make-up of each individual.
- **Nearly 10,000 diseases** – including cystic fibrosis, thalassemia – **are known to be the result of a single gene malfunctioning.** While genes may render some insensitive to certain drugs, **genome**

sequencing has shown that cancer too can be understood from the viewpoint of genetics, rather than being seen as a disease of certain organs.

What are the uses of Genome Sequencing?

- A genome is an organism's complete set of DNA, including all of its genes.
- Genomics is an interdisciplinary field of science focussing on the structure, function, evolution, mapping and editing of genomes.
- Genomics also involves the sequencing and analysis of genomes through uses of high throughput DNA sequencing.
- Advances in genomics have triggered a revolution in discovery-based research and systems biology to facilitate understanding of even the most complex biological systems such as the brain.

23.10.6 National Genomic Grid (NGG)

The government has announced to set up a **National Genomic Grid (NGG).**

About NGG

- It will study genomic data of cancer patients from India.
- It will collect samples from cancer patients, through a network of pan-India collection centres by bringing all cancer treatment institutions on board.
- The grid to be formed will be in line with the National Cancer Tissue Biobank (NCTB) set up at the Indian Institute of Technology, Madras.

NCTB

- **National Cancer Tissue Biobank (NCTB) is a joint initiative of the Department of Science and Technology (DST), Government of India and Indian Institute of Technology, Madras.**
- It collects cancer tissue samples with consent from patients diagnosed with cancer.
- The aim is to provide researchers with high quality of cancer tissues and the patient data in order to facilitate cancer research that will lead to improvements in cancer diagnosis and treatment.
- This research is carried out through the technique of Genome Sequencing.

Significance

- Through NGG, the government seeks to boost cancer research and make treatment viable for people of different economic classes.
- NGG will help to study genomic factors influencing cancer and identifying the right treatment modalities for the Indian population.

23.11 RECOMBINANT DNA TECHNOLOGY (r-DNA TECHNOLOGY)

Recombinant DNA technology is the definite protocol or method deployed to introduce foreign DNA segment (DNA of other species) into host species. The process followed in gene cloning is also called recombinant DNA technology. Recombinant DNA represents DNA from a foreign source.

23.11.1 Applications of Recombinant DNA Technology (r-DNA Technology)

Every biological technology, western pharmacy, doctor's or veterinarian's office, medical testing laboratory, and biological research laboratory is using this technology. The products of r-DNA technology include Recombinant proteins. r-DNA serves as a tool for identification, mapping and sequencing of genes, subsequently determining their functions. Various applications of r-DNA technology are given below:

- **Recombinant human insulin:** Insulin-dependent diabetes has seen major breakthrough in its treatment with the production of recombinant insulin. It is cheaper and easily available as compared to insulin obtained from animal sources.
- **Recombinant human growth hormone:** The patients with pituitary glands generating insufficient quantity of hormone for normal growth and development, it proves to be a boon. Recombinant HGH solved this issue, and is now used therapeutically. Some athletes have been found misusing it as a performance-enhancing drug.
- **Recombinant Vaccines:** Recombinant vector vaccines are bacteria or viruses that are genetically engineered to carry extra genes derived from a pathogen. A recombinant vaccine is a vaccine

produced through recombinant DNA technology. This involves inserting the DNA encoding, an antigen (such as a bacterial surface protein), that stimulates an immune response into bacterial or mammalian cells, expressing the antigen in these cells and then purifying it from them.

- **Recombinant blood clotting factor VIII:** A blood-clotting protein that helps in curing patients with bleeding disorder, haemophilia, due to inability to produce factor VIII in sufficient amount that can support normal blood coagulation. Earlier, when it was not developed, the protein in large quantities of human blood was obtained from multiple donors. And hence, there was a high risk of transmission of blood-borne infectious diseases like HIV and hepatitis B.
- **Recombinant hepatitis B vaccine:** Recombinant hepatitis B vaccine can control infection of hepatitis B, which carries a form of the hepatitis B virus surface antigen, produced in yeast cells. Hepatitis B virus, unlike other common viruses like polio virus, cannot be grown in vitro, it marks to be an important and necessary development.
- **Golden rice:** It is a recombinant variety of rice expressing the enzymes responsible for β-carotene biosynthesis. It is advantageous, being capable to reduce the deficiency of vitamin A in the world's population. Golden rice is not currently in use, due to pending resolution of intellectual property, environmental and nutritional issues.
- **Herbicide and insect-resistant crops:** Commercial varieties of important agricultural crops (like soyabean, maize/corn, sorghum, canola and cotton) have been developed. Such varieties integrate a recombinant gene that cause the resistance to the herbicide glyphosate, and also simplifies weed control by glyphosate application. Several countries use these crops commercially.

23.12 TRANSGENESIS

It a subset of GMOs - Organisms that have inserted DNA that originated in a different species. Transgenesis is the process in which an exogenous gene (external gene) is introduced, called a transgene, into a living organism. This enables the organism to exhibit a new property and transfer the same to the next generation. To facilitate transgenisis, liposomes, plasmid vectors, viral vectors, pronuclear injection, protoplast fusion and ballistic DNA injections are usually deployed. The genetic code is similar for all organisms and hence, there is expression of foreign genes by a transgenic organisms. This implies that similar proteins will be coded by a specific DNA sequence in all organisms.

23.12.1 Transgenic Microbes

The first laboratory-modified organism was bacteria. They are now used for several purposes, specifically in the production of large amounts of pure human proteins for various functions in medicine. Insulin protein treating, clotting factors to treat haemophilia and human growth hormone for treatment of various forms of dwarfism are the result of transgenic microbes.

23.12.2 Transgenic Animals

Through alternation of DNA or insertion of DNA to an animal (sheep, pigs and rats), certain proteins useful for medical treatment can be produced. For instance, Human-alpha-1-antitrypsin, developed in sheep, treats humans with this deficiency and transgenic pigs with human histocompatibility have been studied with the primary objective to check if organs will be suitable for transplant with low chances of rejection.

A knockout mouse is a genetically engineered mouse, in which an existing gene has been knocked out or removed by replacing it or disrupting it with an artificial piece of DNA. The manipulation in the gene results in changes in a mouse's phenotype, which include appearance, behaviour and other observable physical and biochemical characteristics.

23.12.3 Transgenic Plants

To implant desirable traits, like resistance to pests, herbicides, or harsh environmental conditions, improved product shelf life, and increased nutritional value, etc., transgenic plants are being developed. In 1996, the first commercial cultivation of genetically modified plants was performed, post which many modifications are done such as tolerance to the herbicides, glufosinate and glyphosate, resistance to virus damage as in Ring spot, virus-resistant GM papaya, which is grown in Hawaii, and the production of Bt toxin, an insecticide that is non-toxic to mammals.

Most GM crops growing today provide benefits mainly to farmers. GM plants are developed by both private companies and public research institutions like International Maize and Wheat Improvement Centre are involved in development of GM plants. Monsanto, an American Company is an example of such a private company.

23.13 GENETICALLY MODIFIED ORGANISM (GMO)

A Genetically Modified Organism (GMO) or Genetically Engineered Organism (GEO) is an organism with altered genetic material due to application of RDT/genetic engineering techniques. The way it works is: The desirable DNA segment from different sources are combined into one molecule and this creates a new set of genes. This DNA is then transferred into an organism, consequently modifying the genome of the organism. An organism so developed is considered to be a genetically modified organism. GMO bear their application in preparation of medicine, food, etc. The first genetically modified crop was produced in 1982, an antibiotic-resistant tobacco plant. The first field trial occurred in France and USA in 1986.

23.13.1 Genetically Modified Plants

23.13.1.1 Flavr Savr Tomato

It was the first commercially grown genetically modified (GM) food to be granted human consumption licence. It was developed by the Californian company 'Calgene', with the aim to slower the process of ripening in tomato and thus preventing it from softening. It also enables the tomato to retain its natural colour, making it as safe as tomatoes bred by conventional means. Polygalacturonase (PG) is an enzyme produced in plants, which controls the ripening process and restricts the attack of certain bacteria and fungi, which play a role during rotting process.

23.13.1.2 Golden Rice

Beta carotene (Pro-vitamin-A) is required as a source of Vitamin A. So, golden rice is a precursor of Vitamin A. Golden rice is a genetically modified plant, which can be used in those areas where Vitamin A deficiency is common, so it prevents night blindness. Some scientists are against golden rice, as they think it will crossbreed with the wild rice and destroy natural variety. The dark yellow colour shows more β-carotene.

23.13.1.3 Bt Crops

The Belgian company 'Plant Genetic Systems' emerged as the first company (in 1985), aimed to develop genetically engineered tobacco plants with insect tolerance by expression of Cry genes from *Bacillus thuringiensis* bacteria.

Bt stands for *Bacillus thuringiensis,* a Gram-positive bacteria (Gram-positive bacteria do not have an outer cell membrane found in Gram-negative bacteria) that lives in soil and commonly used as a biological alternative to a pesticide. A trans-gene (those gene transfer, i.e., Cry-I AC gene) producing Cry toxin protein extracted by *B. thuringiensis* and introduced in desirable plant to develop Bt-crops. Bt-crops protect them from insect named Lepidoptera (Boll worm/white fly). In 1995, potato plants producing Bt-toxin was the first pesticide producing crop to be approved safe by the Environmental Protection Agency USA.

Note: The first and only transgenic crop approved by Genetic Engineering Approval Committee (GEAC) for commercial cultivation in 6 states, namely Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Tamil Nadu is named the Bt Cotton. India is in the top ranks, accounting for 20 per cent of the total area planted under cotton.

Bollgard I and Bollgard II technology

Bollgard I Bt cotton (single-gene technology) is India's first biotech crop technology approved for commercialisation in India in 2002, followed by Bollgard II–double-gene technology in mid-2006, by the Genetic Engineering Approval Committee (GEAC), the Indian regulatory body for biotech crops.

Bt cotton expressing a *Cry1Ac* gene is grown over a large area in many places of the world, however, there is a major concern that bollworms may develop resistance. Here, a durable resistance strategy against bollworms is used by developing a double gene construct containing *Cry1Ac* and *Cry2Ab* for cotton transformation.

Bollgard I cotton provides in-built protection for cotton against destructive American Bollworm Heliothis infestations and contains an insecticidal protein from a naturally occurring soil microorganism, *Bacillus thuringiensis.*

Bollgard II technology contains a superior double-gene technology–Cry1AC and Cry2Ab which provides protection against bollworms and Spodoptera caterpillar, leading to better boll retention, maximum yield, lower pesticides costs and protection against insect resistance.

Both Bollgard I and Bollgard II insect-protected cotton is widely planted around the world in an environment-friendly way of controlling bollworms.

23.13.1.4 GM Mustard/DMH-11

Dhara Mustard Hybrid-11 (DMH-11) is a *genetically modified* hybrid variety of the mustard species *Brassica juncea*. It was developed by the *University of Delhi*, with the aim of reducing India's demand for edible oil imports.

DMH-11 was created through *transgenic technology*, primarily involving the bar, *barnase* and *barstar* gene system.

The barnase gene confers male sterility, while the Barstar gene restores DMH-11's ability to produce fertile seeds.

The insertion of the third gene bar, enables DMH-11 to produce *phosphinothricin-N-acetyl-transferase*, the enzyme responsible for *Glufosinate* resistance.

This hybrid mustard variety has come under intense public scrutiny, mainly due to concerns regarding DMH-11's potential to adversely affect the environment as well as consumer health. DMH-11 was found not to pose any food allergy risks, and has demonstrated increased yields over existing mustard varieties. Conflicting details and results regarding the field trials and safety evaluations conducted on DMH-11 have delayed its approval for commercial cropping.

The Government had approved the environmental release of Genetically Modified (GM) mustard hybrid DMH-11 and its parental lines during 147th meeting of Genetic Engineering Appraisal Committee (GEAC) on 18 October 2022 for its seed production and testing as per existing ICAR guidelines, conditions imposed by the GEAC while recommending the environmental release of GM mustard hybrid DMH-11 and its parental lines; and other extant rules/regulations prior to commercial release.

The hybrid DMH-11 had been tested against the check varieties Varuna and RL-1359 during Biosafety Research Level Trials (BRL) I and II, where it gave 28.15% high over Varuna during 2010–11 to 2014–15. Field trials for three years were conducted to assess the impact on human health and environment as per the stipulated guidelines and applicable rules. Extensive studies carried out on toxicity, allergenicity, compositional analysis, field trials and environmental safety studies of GM mustard lines against their non-transgenic comparators have provided evidence that the GE mustard hybrid DMH-11 and its parental lines are safe for cultivation and for food and feed use.

23.13.2 Do We Need GM Crops?

Yes and why?

- Higher crop yields.
- Reduced farm costs.
- Increased farm profit.
- Improvement in health and the environment.

No and why?

- **Lack of clarity:** It is clear that the technology of genetic engineering is an evolving one and there is much, especially on its impact on human health and environment that is yet to be understood properly. The scientific community itself seems uncertain about this.
- While there are many in this community who feel that the benefits outweigh the risks, others point to the irreversibility of this technology and uncontrollability of the Genetically Modified Organisms (GMO) once introduced in the ecosystem. Hence, they advocate a precautionary approach towards any open release of GMOs.
- **Threat to domestic crops:** One of the concerns raised strongly by those opposing GM crops in India is that many important crops like rice, brinjal and mustard, among others, originated here, and introducing genetically modified versions of these crops could be a major threat to the vast number of domestic and wild varieties of these crops.
- In fact, globally, there is a clear view that GM crops must not be introduced in centres of origin and diversity. India also has mega biodiversity hotspots like the Eastern Himalayas and the Western Ghats which are rich in biodiversity yet ecologically very sensitive. Hence, it will only be prudent for us to be careful before we jump on to the bandwagon of any technology.